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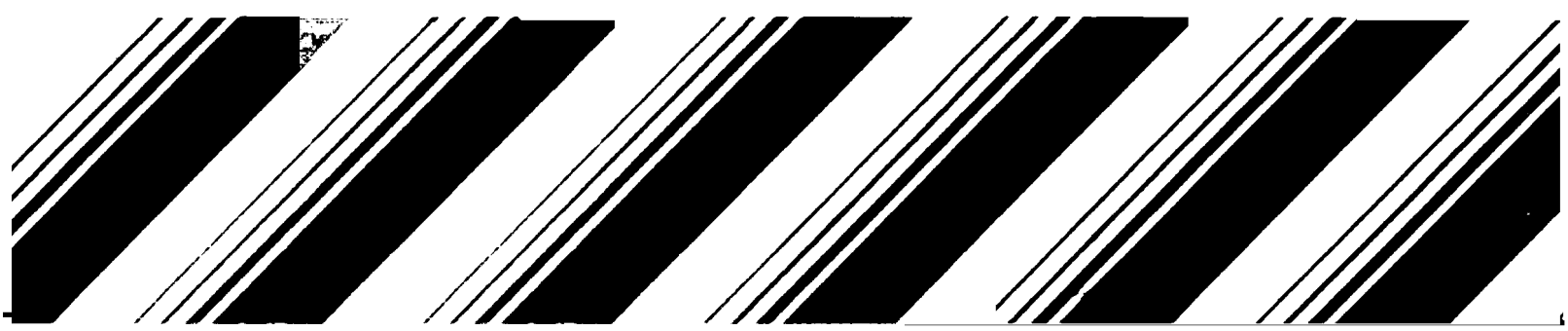
Exposure Assessment for Hexachlorobenzene



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Final Report

Exposure Assessment for Hexachlorobenzene

by

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EXECUTIVE SUMMARY

This report analyzes the exposure of the human population to hexachlorobenzene (HCB), a fully chlorinated, six-membered aromatic carbon compound that has been used as a pesticide and is also present as a contaminant in other agriculturally dispersed organochlorine compounds. HCB also has been used, in the past, in several manufacturing processes not related directly to agriculture. It has been detected in nearly all human fat samples monitored in the U.S.A., and it has become a substance of concern because it may be a human carcinogen. This report is based on information currently available on HCB regarding its sources of production, environmental entry and behavior, detection in environmental media, and routes by which it can be introduced into the human body.

Sources and Environmental Releases

Direct use of HCB as a pesticide has declined sharply since the 1970s. Its principal use was to treat wheat seeds, and, to a lesser extent, it was applied to onions and sorghum. As late as 1985, it was in limited use to prevent wheat smut (or bunt). Although HCB is no longer used as a pesticide in the U.S.A., it is known to be inadvertently produced or introduced during the manufacture of certain pesticides (pentachloronitrobenzene, chlorothalonil, dacthal, picloram, and pentachlorophenol). The total environmental release of HCB associated with the use of these five pesticides has been estimated to be 17.4 kkg/yr. Most of the HCB in this country, however, is produced during the manufacture of certain chlorinated solvents (carbon tetrachloride, perchloroethylene, trichloroethylene, and chlorinated benzenes); total estimated releases from this source vary from 70 to 241 kkg/yr, with most of the releases being emitted to land. HCB is also suspected of being inadvertently produced during the manufacture of many additional pesticides and industrial chlorinated compounds. Nonagricultural uses of HCB are thought to have ceased. They included manufacture of pyrotechnic and ordnance materiel and synthetic rubber production.

Incineration of municipal waste is an additional source of HCB pollution. HCB has been detected in both flue gas and fly ash, and it is thought to be produced during the combustion process; estimated releases from this source vary from 0.06 to 0.5 kkg/yr. Many industrial wastewaters and process waters are chlorinated before being released to the environment. Although the evidence is not conclusive, HCB does not appear to be produced during this chlorination.

Environmental Fate and Transport

Hexachlorobenzene is widely distributed throughout the environment because of its mobility and resistance to degradation. HCB volatilizes from both water and landfills, and it can be removed from the troposphere by precipitation/dry deposition or transport to the stratosphere. Although HCB has been reported to be immobile in soil, it can be transported in runoff water as an adsorbate on suspended particulates. This adsorbed HCB eventually enters surface waters where it may remain suspended or become part of the sediment. Volatilization of HCB from soil can occur when the sorption capacity of the soil for HCB is exceeded. Volatilization is considered to be the principal mechanism for removal of HCB from landfills. Leaching into ground water is not considered to be a severe problem.

Some terrestrial plants can accumulate HCB to an extent greater than the soil HCB content in their roots and also in portions of the plant growing closest to the soil. The roots of carrots have been demonstrated to accumulate HCB to as great an extent as 19 times the soil concentration. Bioaccumulation of HCB also appears to be a problem in the aquatic environment. In controlled aquatic ecosystems, higher food chain organisms always contain more HCB than lower food chain organisms. Nonequilibrium bioaccumulation factors for HCB in algae and fish have been observed to be 24,800 and 2,600, respectively. The equilibrium or steady-state value for fish is expected to be much higher. Freshwater clams remove HCB from water rapidly but also depurate the unchanged chemical when placed in uncontaminated water. Experiments conducted with a group of ponds showed that sediment and aquatic biota can act as a short-term sink for HCB and thereafter as a long-term source.

Microorganisms appear to have little or no ability to metabolize HCB. Soil cultures, aerobic and anaerobic mixed cultures, and activated sludge demonstrated no detectable degradation of this compound. Aerobic mixed cultures also showed no tendency to acclimate themselves to HCB.

Seventy percent of the HCB absorbed by wheat plants appears to become incorporated into high molecular weight organic matter, nonextractable with water or organic solvents. Less than 1 percent of the absorbed HCB was transformed to pentachlorothiophenol. The remainder of the extractable material from wheat was principally unchanged HCB. In an aquatic microcosm to which ^{14}C-HCB had been added, a very small amount of pentachlorophenol was identified in algae and mosquito larvae as a degradation product.

Monitoring Data

Monitoring data confirm that HCB is a ubiquitous pollutant; it has been detected in all environmental media and in numerous types of living organisms, including insects, aquatic biota, birds, and mammals. The data have been organized into five subsections: human food (FDA), HCB in fish, starlings, and ducks (Fish and Wildlife Service), HCB in livestock (USDA), the National Human Adipose Tissue Survey (EPA), and monitoring data from the open literature and EPA's STORET data base.

The human diet studies indicate a rise in both HCB intake and HCB detection frequency for toddlers and infants during the late 1970s followed by a decrease in the 1980s. Dairy products, meat, fish, poultry, and prepared foods that contained oils and fats accounted for the majority of HCB intake.

HCB residue levels and occurrence frequencies decreased significantly in freshwater fish between 1976-1977 and 1978-1979; no significant change was evident between the latter period and 1980-1981. Occurrence of HCB detection in starlings has generally decreased during the period 1972-1982, except in the western region of the U.S.A. Nationwide occurrence frequency of HCB detection in duckwings was highest in the 1976-1977 hunting season during the period 1972-1982; generally, occurrence frequencies from Atlantic and Pacific sampling regions were higher than those from the central portion of the U.S.A.

Data on HCB detection in domestic livestock fat samples exhibit a significant increase in occurrence frequencies during the period 1974-1978 compared to 1972-1973 and 1979-1984; regional variability during 1972-1984 was significant. Detection of HCB in fat samples from imported meat and poultry has declined steadily during the period 1979-1984.

HCB detection frequency in monitored human fat samples has increased steadily from 97.6 percent in 1974 to 100 percent in 1983. Residue levels, however, exhibit a quadratic trend, increasing to a maximum in 1979 and decreasing thereafter. Detection frequencies and residue levels show no significant age, sex, or race differences; geographic differences in residue reflect higher levels in the West Census Region than in the North Central and South Regions.

Monitoring data on environmental levels of HCB indicate detection in all areas of the country with consistent detection in sediments and in the surface waters and soils of industrialized areas. The nature of the data, however, makes inter-reference comparisons difficult. The highest

concentrations of HCB in ambient air and soil were obtained from samples gathered near industrial facilities. Samples of aquatic sediment from the surface waters of industrial areas also exhibited higher concentrations of HCB than were found in sediments from nonindustrial areas.

Modeling Data

Two sets of modeling data were developed for this report: (1) estimated HCB concentrations in air downstream of seven industrial incinerators and (2) estimated HCB concentrations in air and ground water resulting from landfill releases. It was found that HCB concentrations in air downstream of an industrial incinerator may be significant, depending on the quantity of HCB incinerated and the destruction efficiency of the incinerator. Concentrations in air resulting from volatilization of HCB from landfills may also be important, but they are dependent on the amount of HCB in the landfill, the depth of HCB in the landfill, and the material used as the cover (if any). HCB in landfills should not have a critical effect on ground-water quality, since it is immobile in soil.

Exposure Scenarios

Exposure scenarios were developed for inhalation of ambient air, ingestion of drinking water, and ingestion of food. Exposures from food ingestion were found to be the most significant (68 ug/yr based on the FDA total diet data for adults), followed by drinking water ingestion (best estimate of exposure is < 4.4 ug/yr based on monitoring data for ambient drinking water), and ambient air inhalation (best estimate of exposure is 3.5 ug/yr based on monitoring data for ambient air). Other specific scenarios that were developed (e.g., inhalation of air downstream of an incinerator, ingestion of contaminated ground water, consumption of contaminated fish, ingestion of pesticide treated crops) also supported the finding that food is the major route of exposure.

Furthermore, results from the pharmacokinetic modeling of the NHATS survey data showed that food is probably the major route of human exposure. HCB levels found in ambient air and drinking water are approximately one to two orders of magnitude too low to cause the steady-state HCB exposures estimated by the model. However, the average adult intake of HCB estimated by FDA through their Total Diet Study (0.02 to 0.004 ug/kg/day) compares quite well with the exposures estimated by the model (0.004 to 0.007 ug/kg/day).

Conclusions, Hypotheses, and Recommendations

The most significant conclusion is that food ingestion appears to be the major route of human exposure to HCB, although some contribution to total exposure will be made through the inhalation of ambient air and possibly through the ingestion of drinking water. HCB detection frequency in domestic and imported meat and poultry, daily dietary intakes, and levels in human adipose tissues have all decreased during the period 1979-1984. No universal trends were observed for HCB detection frequencies in wildlife (starlings, ducks, and freshwater fish).

Hypotheses were presented in this report to address the following two phenomena: (1) the consistent increase in detection frequencies of HCB found in fat samples taken from livestock from 1974 to 1978 and (2) the relatively high concentrations found in the NHATS survey data for HCB in the Pacific Census Division. It was hypothesized that ingestion by farm animals of feedstuffs contaminated with a higher than usual level of HCB was responsible for the increased HCB level in livestock during 1974-1978. A more concentrated use of HCB-containing pesticides in the Northwest was speculated to add to the increased HCB levels in human adipose tissue in the Pacific Census Division, although no conclusive hypothesis could be reached about this phenomenon.

Several recommendations were made, including the development of a more comprehensive source assessment, additional monitoring work (for pesticides; air downstream of an incinerator; biota, water, and sediments of shorelines; and ambient air and water), and a study of temporal differences among existing data sets (e.g., USDA data, FDA data, and NHATS data).

1. INTRODUCTION

Hexachlorobenzene (HCB) is a very stable, ubiquitous chlorinated aromatic compound that originates from a variety of sources. The U.S. Environmental Protection Agency (EPA) is concerned with HCB because it has been detected in nearly all human fat samples and because it is suspected of being a human carcinogen. To address these concerns, the Office of Toxic Substances developed an overall work plan for an Agency-wide strategy for assessing HCB. Besides the Office of Toxic Substances, the following EPA offices are working on this coordinated effort: Research and Development (ORD), Solid Waste (OSW), Remedial and Emergency Response (OERR), Pesticide Programs (OPP), Air Quality Planning and Standards (OAQPS), Drinking Water (ODW), and Water Regulation and Standards (OWRS). The final goal of this coordinated effort is to develop an Agency-wide risk management strategy to control the risks, if significant, associated with HCB. In support of that goal, this report, prepared under the guidance of the Exposure Evaluation Division of OTS, provides an exposure assessment for HCB.

Several offices within the EPA have been very helpful in providing information for this exposure assessment, including the following:

- Environmental Research Laboratory, Corvallis, Oregon. Provided published and unpublished research papers dealing with physical-chemical properties of HCB.

- Office of Water Regulations and Standards, Washington, D.C. Assisted in obtaining and interpreting STORET data.

- Office of Pesticide Programs, Washington, D.C. Supplied retrievals from the Tolerance Assessment System and in-house monitoring data bases.

- Office of Air Quality Planning and Standards, Research Triangle Park, NC. Provided a 1984 assessment of HCB sources and releases to the atmosphere. This report served as a starting point and guide to our efforts to assess the magnitude and impact of HCB releases to air.

In addition to this assistance from the EPA, several other government agencies cooperated by providing data and information:

- U.S. Department of Interior, Fish and Wildlife Service.

  - Columbia National Fisheries Lab. Furnished results of freshwater fish monitoring programs for 1976-1979.

- Patuxent Wildlife Research Center. Provided published and unpublished results of starling and waterfowl monitoring programs.

- U.S. Department of Health and Human Services.

  - Food and Drug Administration. Furnished published and unpublished results of FDA total diet studies and FDA surveillance and compliance monitoring data for HCB from 1978-1984.

  - National Institute for Occupational Safety and Health. Supplied retrievals from in-house data bases (NOHS and CRF).

  - Occupational Safety and Health Administration. Furnished retrievals from in-house data bases (NIOSHTIC and OHDS4).

- U.S. Department of Agriculture, Food Safety and Inspection Service. Provided data on HCB residue levels in meat and poultry from 1972 to 1984.

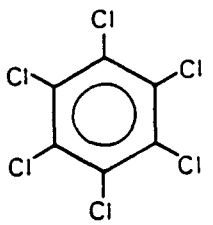
In general, this report is organized by the major components of an exposure assessment. Following this introduction, Section 2 defines the chemical's identity and lists the known properties of HCB. Section 3 presents a source assessment, which contains estimates on HCB releases to the environment. Section 4 provides information on the environmental fate of HCB in air, water, and soil, along with a discussion of the bioaccumulation of HCB in plants and animals. A discussion of the available monitoring data is included in Section 5. Section 6 presents the modeling results of the estimated HCB concentrations in air near incinerators that may release HCB and in air and ground water near model landfills that contain HCB. Several exposure scenarios are presented in Section 7. Finally, conclusions and hypotheses are provided in Section 8.

2. GENERAL INFORMATION

This section presents background information on the chemical identity and the chemical-physical properties of HCB. Subsection 2.1 discusses the physical form, molecular formula and structure, and other names by which HCB is known. Subsection 2.2 is a compilation of the chemical and physical properties of HCB that influence its behavior in the environment.

2.1 Chemical Identity

Hexachlorobenzene (CAS No. 118-74-1), or HCB, is a colorless to white crystalline solid (Verschueren 1983). It is a chlorinated aromatic hydrocarbon. The chemical formula of HCB is C_6Cl_6, and the structure is:



HCB is known by the following names:

- Hexachlorobenzene
- Perchlorobenzene
- Amatin
- Anticarie
- Bunt-Cure
- Bunt-No-More
- Co-op Hexa
- Granox NM
- HEXA C.B.
- Julin's Carbon Chloride
- No Bunt
- No Bunt 40
- No Bunt 80
- No Bunt liquid
- Pentachlorophenyl chloride
- Phenyl perchloryl
- Sanocide
- Smut-Go
- Snieciotox

2.2 Chemical and Physical Properties

The chemical and physical properties of HCB gathered from several references are presented in Table 2-1. Of particular importance for assessing environmental fate and potential for exposure are HCB's low solubility in water and its low vapor pressure.

Table 2-1. Physical and Chemical Properties of Hexachlorobenzene

Property	Condition/Comment	Value	Reference
Molecular weight (MW)		284.79	Weast (1974)
Melting point		229°C	Hawley (1981)
Boiling point	742 mm-Hg	309°C	Perry & Chilton (1973)
	760 mm-Hg	322°C, sublimes	Weast (1974)
	760 mm-Hg	326°C	Hawley (1981)
Equilibrium vapor concentration[a]	20°C	0.17 mg/m^3	Calculated using $Ceq = \frac{Pvp}{RT}$
Vapor pressure	15°C	0.40×10^{-5} mm-Hg	Farmer et al. (1980)
	20°C	1.089×10^{-5} mm-Hg	Verschueren (1983)
	25°C	1.91×10^{-5} mm-Hg	Farmer et al. (1980)
	35°C	6.40×10^{-5} mm-Hg	Farmer et al. (1980)
	114.4°C	1 mm-Hg	Weast (1974)
	149.3°C	5 mm-Hg	Perry & Chilton (1973)
	166.4°C	10 mm-Hg	Perry & Chilton (1973)
	185.7°C	20 mm-Hg	Perry & Chilton (1973)
	206 °C	40 mm-Hg	Weast (1974)
	235.5°C	100 mm-Hg	Weast (1974)
	283.5°C	400 mm-Hg	Weast (1974)
	309.4°C	740 mm-Hg	Weast (1974)
Specific gravity	23°C	2.044	Verschueren (1983)
Density of solid	23°C	1.57 g/cm^3	Weast (1974)
Relative "vapor density"		9.84 (air=1)	Verschueren (1983)
Solubility	16°C	3.0 ug/l	Dime (1982)
water	20°C	4.9 ug/l	Chiou and Schmedding (1982)
	25°C	5.0 ug/l	Weil et al. (1974)
	25°C	6 ug/l	Verschueren (1983)
alcohol		sparingly soluble	Weast (1974)
ether		soluble	Weast (1974)
chloroform		soluble	Weast (1974)
benzene		very soluble	Weast (1974)
Flash point		242°C	Hawley (1981)

Table 2-1. (continued)

Property	Condition/Comment	Value	Reference
Critical temperature		551°C	Kao and Poffenberger (1979)
Critical pressure		2.847 kPa	Kao and Poffenberger (1979)
Critical density		0.518 g/cm^3	Kao and Poffenberger (1979)
Adsorption capacity on activated charcoal		450 mg/g	Ramanathan (1979)
Log octanol-water partition coefficient (log P or log K_{ow})	Experimental value	5.2	Platford et al. (1982)
	Experimental value	5.31	Watarai et al. (1982)
	Experimental value	5.44	Briggs (1981)
	Experimental value	5.50	Chiou and Schmedding (1982)
Soil/sediment adsorption coefficient (K_{oc})	Ava silty clay loam	1.15×10^4	Griffin and Chou (1981) (K_{oc} = k/mass fraction organic carbon)
	Batcombe silt loam	1.78×10^4	Briggs (1981)
	Panoche sandy clay loam	7.36×10^4	Dime (1982)
	Montezuma clay	1.74×10^4	Dime (1982)
	Tule	4.98×10^4	Dime (1982)
	Theoretical	1.6×10^4	Calculated using equation $\log K_{oc} = 0.544 \log k_{ow} + 1.377$ (Lyman 1982)
Henry's law constant	Experimental value	1.7×10^{-3} $\frac{atm\text{-}m^3}{mole}$	USEPA (1983)
	Theoretical	1.05×10^{-3} $\frac{atm\text{-}m^3}{mole}$	Calculated (at 25°C) using $H = \frac{V_p(mm\text{-}Hg)\ MW\ (g/mole)}{Sol\ (mg/l)\ 760\ (mm/atm)}$

[a]Equilibrium vapor concentration represents the air saturation concentration under ideal conditions. It is useful in calculating air inhalation exposures. The calculation is based on the ideal gas law. In our equation, P_{vp} is the vapor pressure in atmospheres at 293°K, R is the universal gas constant (0.08205 l-atm/mole-°K), and T is temperature in °K (293°K). C_{eq} is the equilibrium vapor concentration in moles/liter which is then converted to mg/m^3.

2.3 References

Briggs GG. 1981. Theoretical and experimental relationships between soil adsorption, octanol-water partition coefficients, water solubilities, bioconcentration factors, and the parachor. J. Agric Food Chem. 29(5):1050-1059.

Chiou CT, Schmedding DW. 1982. Partitioning of organic compounds in octanol-water systems. Environmental Science and Technology. 16(1):4-10.

Dime RA. 1982. Environmental fate of hexachlorobenzene. Ph.D. Dissertation, University Microfilms International. Order No. 82-20134.

Farmer WJ, Yang MS, Letey J, Spencer WF. 1980. Hexachlorobenzene: its vapor pressure and vapor phase diffusion in soil. Soil Sci. Am. J. 44:676-680.

Griffin RA, Chou SFJ. 1981. Movement of PCB's and other persistent compounds through soil. Water Science and Technology 13:1153-1163.

Hawley GG. 1981. The condensed chemical dictionary. New York, NY: Van Nostrand Reinhold Co. pp. 526.

Kao CI, Poffenberger N. 1979. Chlorocarbons: chlorinated benzenes. Kirk-Othmer encyclopedia of chemical technology, 3rd ed. 5:799-808.

Lyman W. 1982. Handbook of chemical property estimation methods. New York, NY: McGraw-Hill Book Co. 4:1-32, 15:1-34, 5:1-30.

Perry RH, Chilton CH. 1973. Chemical engineer's handbook. New York, NY: McGraw-Hill Book Co. pp. 3-53.

Platford RF, Carey JH, Hale EJ. 1982. The environmental significance of surface films. Environmental Pollution (Series B) 3:125-128.

Ramanathan M. 1979. Water pollution. Kirk-Othmer encyclopedia of chemical technology, 3rd ed. 24:306.

USEPA. 1983. Office of Research and Development. U.S. Environmental Protection Agency. Treatability manual: Volume 1 Treatability data. Washington, DC: U.S. Environmental Protection Agency. EPA-600/2-82-001a.

Verschueren K. 1983. Handbook of environmental data on organic chemicals. New York, NY: Van Nostrand Reinhold Co.

Watarai H, Tanaka M, Suzuki N. 1982. Determination of partition coefficients of halobenzenes in heptane/water and 1-octanol/water systems and comparison with the scaled particle calculation. Analytical Chemistry 54(4):702-705.

Weast RC. 1974. Handbook of chemistry and physics. Cleveland, OH: CRC Press. C1-C658, D170-D186.

Weil VL, Dure G, Quentin KE. 1974. Wasserloslichkeit von insektiziden chlorierten kohlenwasserstoffen und polychlorierten biphenylen im hinblick auf eine gewasserbelastung mit diesen stoffen. Z. Wasser-Abwasser - Forsch. 6:169-175.

3. SOURCE DATA

A source assessment or materials balance is one of the major building blocks of an exposure assessment. This section contains the compilation of source data that were obtained under this task. It is based mostly on previous assessments of HCB sources, although it also contains a considerable amount of new or updated information, especially for pesticidal uses.

Table 3-1 summarizes the estimates of current environmental releases of HCB that are discussed in this section. The direct use of HCB as a fungicide appears to have ceased during 1985 because of the voluntary cancellation of pesticide registrations by all HCB pesticide registrants. The majority of the HCB generated occurs as a byproduct during the manufacture of chlorinated solvents. This source also accounts for most of the releases to the environment, although other sources may be more important in terms of actual exposure of humans and other living organisms to HCB. This is because nearly all the HCB produced during the manufacture of chlorinated solvents ends up in solid wastes, which are mostly destroyed through incineration or disposed of in RCRA approved landfills. However, most HCB produced during pesticide manufacture is contained in the product, which is directly applied to soil or crops. Although historical sources of HCB could not be quantified, they may also be a significant source today because of the persistence of HCB.. With the possible exception of landfills that contain HCB, other known sources (manufacture of other chlorinated compounds and municipal incineration) appear to be insignificant.

This section is organized into three subsections. Subsection 3.1 contains information on the past uses of HCB including pesticide and industrial uses. Subsection 3.2 presents information on the inadvertent production of HCB during the manufacture of pesticides, chlorinated solvents, and other chlorinated industrial chemicals. This subsection also presents information on facilities that are known to produce or are suspected of having previously produced HCB. Subsection 3.3 discusses three miscellaneous sources of HCB production: (1) municipal waste incineration, (2) wastewater and process water chlorination, and (3) landfills that are known to contain HCB.

3.1 Uses of HCB

There have been many commercial uses of HCB. The most significant use has been as a pesticide, but HCB has been reported to be used in at least eight other commercial products, processes, or operations. A discussion of these uses is presented below.

Table 3-1. Summary of Source Data

Source of HCB	Estimated releases (kg) Air	Water	Land	Total
1. Manufacture of chlorinated solvents	343 - 11,270[a]	0 - 41	70,000 - 230,000	70,343 - 241,311
2. Manufacture of other chlorinated compounds[b]	2.6[a]	29	13	45
3. Municipal incineration	57 - 454	~0	~0	57 - 454
4. Pesticide use[c]				
Pentachloronitrobenzene (PCNB)	d	d	d	5,675
Chlorothalonil	d	d	d	1,700
DCPA (dacthal)	d	d	d	6,540
Picloram	d	d	d	91
Pentachlorophenol	d	d	d	3,360
5. Historical sources[e]	d	d	d	f
Total				87,811 - 259,176

[a]Estimated incinerator emissions assuming a 99.9 to 99.99 percent range in incinerator destruction efficiency.
[b]This includes all other chlorinated compounds besides chlorinated solvents.
[c]This only includes those pesticides that are known to contain HCB.
[d]Amounts to each medium could not be estimated.
[e]Historical sources include facilities that previously generated HCB, but are no longer producing HCB or are no longer in operation.
[f]Could not be quantified.

3.1.1 Pesticide Uses of HCB

The manufacturer of the last registered HCB pesticide voluntarily requested cancellation of its products in March 1985 (personal communication between HM Jacoby, Office of Pesticide Programs, USEPA, and Greg Schweer, Office of Toxic Substances, USEPA, on January 24, 1986). After existing inventories of these pesticides are depleted, HCB pesticides can no longer be legally used in the United States. Most manufacturers of registered HCB pesticides requested cancellation of their products in July 1984; existing inventories were allowed to be used until the supply was exhausted or until July 1985, whichever came earlier (49 FR 23440).

One producer (Chipman Chemicals, Inc.) of a pesticide formulated with HCB (GRANOX, which is a mixture of HCB and maneb) was contacted to learn whether they still had any supplies of the unsold pesticide (Farm Chemicals Handbook 1986). They reported that they had not had any stock of this product since September 1985 (personal communication between G. Stinnett, Versar Inc., and G. Wasmand, Chipman Chemicals, Inc. of River Rouge, Michigan, on April 25, 1986). In addition, one of the two registered distributors of GRANOX was contacted, and they also reported that they did not have any supplies of the pesticide in stock (personal communication between C. Carpenter, Versar Inc., and Marshall Thomas, Marshall Thomas Distributing Co., on April 17, 1986.)

Prior to the registration cancellations, HCB had been registered as a seed protectant for use on several grain and field crops, including barley, beans, corn, cotton, flax, oats, onions, peanuts, peas, sorghum, soybeans, rye, and wheat (Devine 1982, Pelletier 1985). HCB was principally used to treat wheat seed and to a minor extent was used to treat onions and sorghum. The treatment rates were 0.2 to 2.0 ounces/bushel of wheat seed, 6 to 16 ounces/bushel of onion seed, and 0.32 to 0.75 ounces/bushel of sorghum seed. The major geographic areas of use were in the Northwest for wheat and onions and in Colorado for sorghum. HCB use for seed treatment of the remaining crops listed above was negligible (Pelletier 1985). Figure 3-1 provides a map of geographic areas of probable concentrated use.

Only very limited information on historical production and use of HCB as a pesticide is available. Mumma and Lawless (1975) estimated HCB pesticide production volumes of 760,000 pounds in 1958, 720,000 pounds in 1959, 440,000 pounds in 1960, and 700,000 pounds in 1973. Blackwood and Sipes (1979) estimated a production volume of 3,200,000 pounds in 1975 (estimate may be for all HCB uses). Dime (1982) reported that use of HCB for pesticidal purposes increased from about 1,800 lbs in 1966 to about

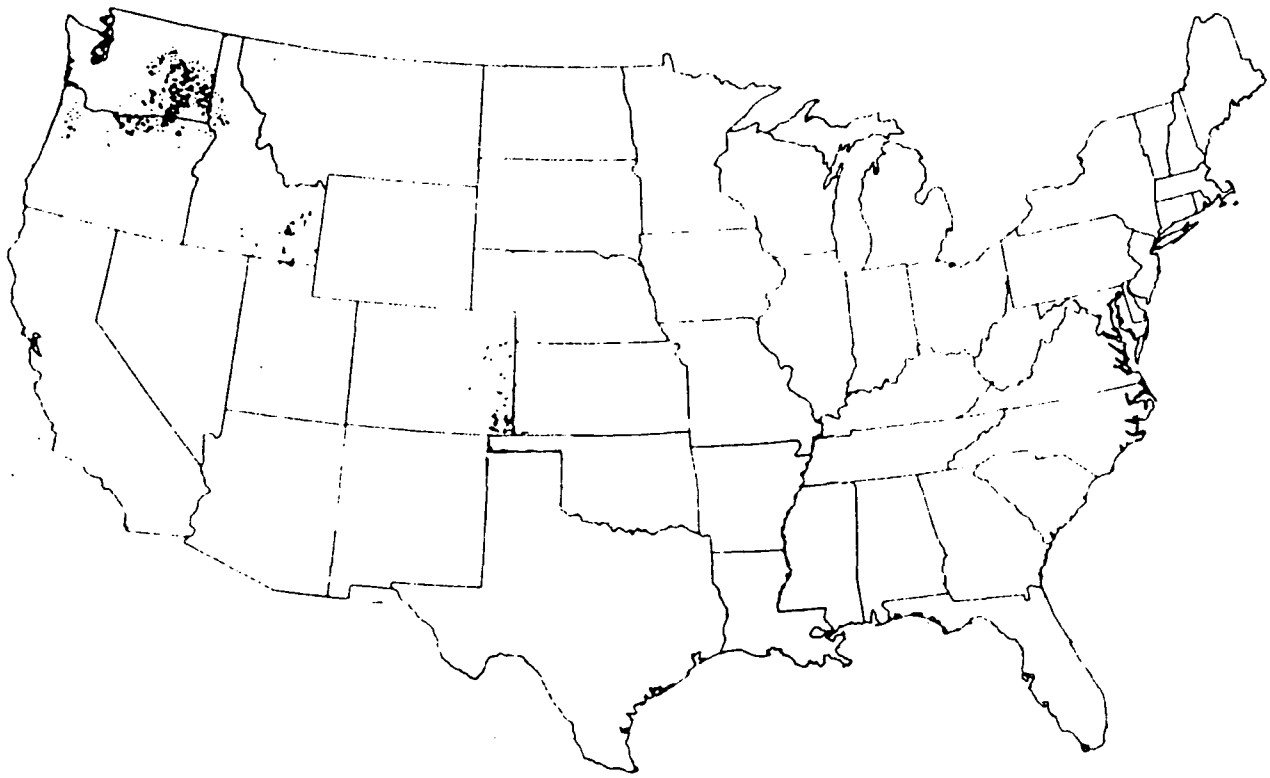


Figure 3-1. Major geographic areas of HCB use [constructed by overlaying maps from the 1978 Census of Agriculture (U.S. Department of Commerce 1982) of "crop acreage harvested" for wheat in the Northwest U.S. and sorghum in Colorado. No maps available for onion acreage. Darkened areas of map indicate usage areas].

14,000 in 1971. It has been estimated that the supply of HCB available for pesticide use declined from more than 100,000 pounds per year prior to 1977 to less than 50,000 pounds per year in the early 1980s. (Personal communication between G. Schweer, Office of Toxic Substances, USEPA, and T. Burkhalter, Office of Pesticide Programs, USEPA).

3.1.2 Other Uses of HCB

Other commercial uses of HCB in the U.S. have essentially ceased as supplies diminished and acceptable substitutes were found. From a historical point of view, however, HCB was used in a wide range of commercial operations; these uses are summarized in Table 3-2. A brief description of each of the identified historical uses of HCB is given below.

- Pyrotechnic and Ordnance Materiels Production - Several sources have indicated that HCB was used in the production of pyrotechnic (e.g., signal flares) and ordinance (e.g., tracer bullets) materiels (Brooks and Hunt 1984, Quinlivan 1975, and Blackwood and Sipes 1979). Information on this former use of HCB is very limited, however, mostly because of the secretive nature of munition production operations. The use of HCB in this application appears to have diminished in the early 1970s as commercial sales of HCB declined and acceptable substitutes were found. By the mid-to-late 1970s, the use of HCB in pyrotechnic and ordinance materiels production should have been completely replaced by more dependable long-term substitutes.

- Synthetic Rubber Production - Mumma and Lawless (1975) reported that in 1974 the largest domestic supplier of HCB was diverting its entire HCB production volume into the manufacture of nitroso and styrene rubber for use in automobile tires. HCB functioned as a peptizing agent, which at the time was a new type of peptizing agent to the rubber industry. This was essentially an experimental use of HCB and as sales declined, several chemicals were likely substituted for HCB. Any significant use of HCB in this capacity from the mid-1970s to the present is very remote (Brooks and Hunt 1979). A characterization of rubber industry wastes in a treatability manual published by EPA did not include HCB as a waste stream constituent (USEPA 1983a).

- Primary Aluminum Production - Quinlivan et al. (1975) reported that HCB has been used as a fluxing agent in the production of aluminium. However, a 1975 survey of the several aluminum manufacturers indicated HCB was not being used for this purpose.

Table 3-2. Other Reported Uses of HCB

1.	Pyrotechnic materials
2.	Synthetic rubber production
3.	Primary aluminum production
4.	Wood preservation
5.	Graphite electrode production
6.	Intermediate in dye manufacturing
7.	Organic synthesis
8.	Feedstock in the production of pentachlorophenol

Sources: Mumma and Lawless (1975), Brooks and Hunt (1984), Blackwood and Sipes (1979), Quinlivan et al. (1975).

If HCB was used in this capacity, the quantity used should have been small and several compounds could have been substituted. A 1980 draft of Efficient Limitations Guidelines for the Aluminum industry did not mention the use of HCB in its description of the flexing process. During the selection of priority pollutants for the establishment of these guidelines, HCB was not detected in any of the wastewater samples analyzed (USEPA) 1980a). A treatability manual published by the Office of Research and Development of EPA did not list HCB in the wastewater characterization of the Aluminum Industry (USEPA 1983c).

- Wood Preservation - The use of HCB as a wood preservative was reported in Mumma and Lawless (1975). However, Quinlivan et al. (1975) contacted several major wood preserving companies and none was aware of any use of HCB as a wood preservative. Brooks and Hunt (1979) hypothesized that this confusion occurred because of the similar abbreviation between HCB and a compound commonly used in wood preservation (BHC or *q*-hexachlorocyclohexane). According to the American Wood Preservers Association, HCB was not used as a wood preservative in 1980 (Brooks and Hunt 1984). More recently, Farm Chemicals Handbook (1986) reported that HCB was not available as a wood preservative and Environ (1985) indicated that it was not found in RCRA wastes from wood preservative facilities.

- Graphite Electrode Production - Mumma and Lawless (1975) reported that HCB was used as a porosity controller in the manufacture of graphite electrodes. However, a survey of graphite electrode manufacturers, which was reported by Quinlivan et al. (1975), indicated that HCB was not used for this purpose. No other data are available to confirm this potential use of HCB. However, the use of oil-impregnated graphite electrodes to manufacture chlorine is known to have resulted in the inadvertent production of HCB. Most chlorine manufacturing facilities today use metal electrodes, which do not produce HCB as a byproduct.

- Dye Manufacturing - HCB was listed in both Blackwood and Sipes (1979) and Mumma and Lawless (1975) as a possible intermediate in dye manufacturing. A treatability manual, published in 1983 by the USEPA, cited a detection of HCB in its waste stream characterization for textile manufacturers. Since this same concentration was listed for the influent stream, the HCB contamination was probably not due to an industrial practice in the textile plant (USEPA 1983c). When contacted, a representative of a dye works said that HCB was not used at that facility and, to his knowledge, not used by anyone as an intermediate in the industry. (Personal communication between Nick Stabulas of Brooks Textile Dye Works and Georgianne Stinnett of Versar Inc. on April 22, 1986.)

- Other Uses - Very little is known about the remaining historical uses of HCB (i.e., organic synthesis, and a feedstock in the production of pentachlorophenol). They were mentioned as possible uses in Blackwood and Sipes (1979) and the use as an intermediate in organic synthesis was mentioned in Mumma and Lawless (1975). Other than the sources mentioned, data on these historical uses of HCB could not be located.

3.2 Inadvertent Production

HCB is known to be produced during the manufacture of several commercial products including pesticides, chlorinated solvents, and other chlorinated compounds. This section discusses the inadvertent production of HCB and provides estimates of HCB releases to the various environmental media.

3.2.1 Pesticides

HCB is known to be inadvertently produced during the manufacture of several pesticides and is suspected of being produced or introduced as an impurity during the manufacture of others (Mould et al. 1985). Five pesticides (PCNB, chlorothalonil, dacthal, picloram, and pentachlorophenol) have been identified as containing HCB in the technical grade product. This section summarizes for each of these five pesticides, the uses, HCB contaminant levels, production/consumption, and estimated current environmental releases of HCB.

In addition to these five pesticides, several triazine herbicides were reported to contain low levels of HCB, 0.025 to 0.25 ppm (Mumma and Lawless 1975). Tobin (unpublished) has reported that a historical sample of aldrin, one of the chlorinated cyclopentadiene derived pesticides, was recently analyzed and found to contain 65 ppm of HCB.

(1) Pentachloronitrobenzene (PCNB)

Uses - PCNB is a fungicide used primarily as a soil and seed treatment agent for field crops, vegetables, turf, and ornamentals. Table 3-3 summarizes the current (circa 1983-1984) uses of PCNB. Cotton, turf, and soybeans are the largest volume use sites and account respectively, for 19 percent, 18 percent, and 14 percent of total estimated U.S. consumption. Major geographic areas of use are in the Southeast and Northwest/California regions. Although they are not major use sites, some crops have rather significant portions of their total acreage treated with PCNB; barley, Brussels sprouts, cabbage, garlic, peppers, and rice have from 11 to 29 percent of their total planted acreage treated with PCNB. Figure 3-2 provides a map of geographic areas of probable concentrated use of PCNB.

Table 3-3. Domestic PCNB Usage by Site, 1983-1984

Site	Use (1,000 lbs)	Percent of total use	Acres treated (1,000)	Percent of site acreage treated	Regional usage	Tolerances[a] (ppm)
Agricultural uses						
Barley[b]	82-84	4	958	12	WA, OR, CA	-
Beans	26-35	1	13	4	MI, NE, NY, TN, VA, NC	0.1
Broccoli	8-10	<1	0.2	<1	OR	0.1
Brussels sprouts	20-22	1	0.7	13	CA, OR	0.1
Cabbage	195-198	9	10.5	11	NY, MI, GA, OR, NC	0.1
Cauliflower	83-85	4	3.3	8	MI, NY, OR	0.1
Cotton - soil	370-390	17	400	4	Southeast	-
Cotton - seed[b]	45-50	2	1,000	7	Southeast	0.1
Crucifer seedbeds	24-37	1	0.9	Unknown	CA, GA, NY	-
Garlic	35-37	2	1.8	14	CA	-
Oats[b]	26-28	1	222	1	Northwest, CA	-
Peanuts	75-150	5	11	<1	Southeast	0.1
Peppers	101-103	4	6.8	12	GA, LA, MS, NC, TN	0.1
Potatoes	67-108	4	5.6	<1	WA, OR, ID, WI	0.1
Rice[b]	36-38	2	800	29	AR, MS, LA, TX	-
Soybeans[b]	304-306	14	7,100	10	AL, AR, LA, MS	-
Sugarbeets[b]	1-2	<1	Unknown	Unknown	MN, CA, ID, CO, NB, ND, WA	-
Tomatoes	20-22	1	2.7	1	GA, LA, MS, NC, TN, TX	0.1
Wheat[b]	101-103	4	3,000	4	WA, OR, CA, AR, TX	-
Nonagricultral Uses						
Ornamentals	60-200	6	Unknown	Unknown	US (primarly WA, CA, FL)	-
Turf	360-450	18	14.7	Unknown	US	-
Total	2041-2458	100	12,751			

[a] All tolerences are interim except for cotton seed. There is also a tolerance of 0.1 ppm for edible banana pulp.
[b] Indicates used treatment; all other sites are soil treated.

Sources: Torla (1985); USEPA (1981a); 40 CFR 180.291.

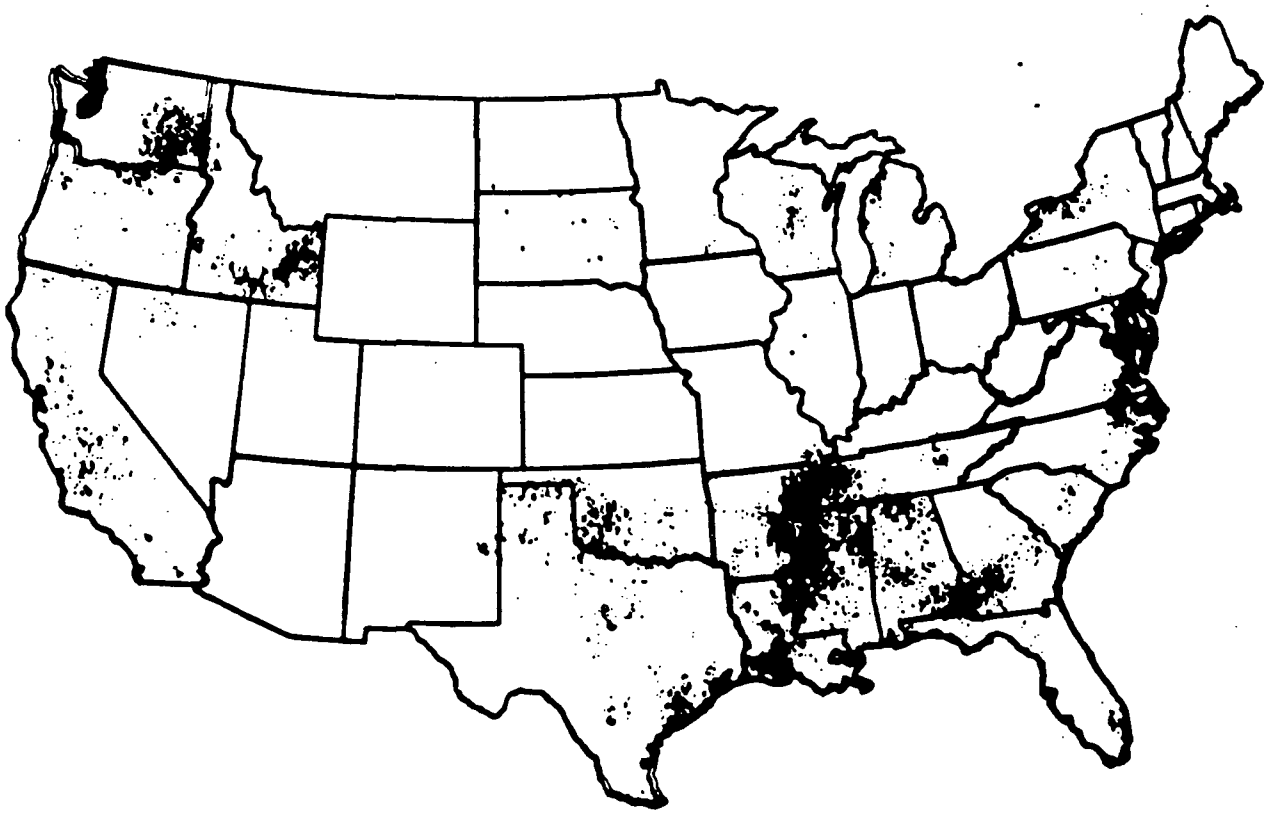


Figure 3-2. Major geographic areas of PCNB use [constructed by overlaying maps from the 1978 Census of Agriculture (U.S. Department of Commerce 1982) of "crop acreage harvested" for the following crops using the regional PCNB usage information in Table 3-2: barley, beans, cotten, oats, peanuts, potatoes, rice, soybeans, tomatoes, and wheat. Maps were not available for other crop uses. Darkened areas of map indicate usage areas].

HCB Level in PCNB - By terms of the termination of EPA's PCNB Rebuttal Presumption Against Registration in 1982 (47 FR 18177), PCNB registrants agreed to reduce HCB contaminant levels in PCNB to a maximum of 0.5 percent by April 1983 and to a maximum of 0.1 percent by April 1988. The limited information available on historical levels of HCB in PCNB was summarized in EPA's Position 1 Document in 1977 (USEPA 1977). The sole U.S. manufacturer reported the contaminant level to be 1 percent in 1976. In 1971, the technical grade PCNB used in a West German bioassay contained 2.7 percent HCB, and the suspected HCB level in a 1966 domestic bioassay was 11 percent.

Production/Consumption of PCNB - Domestic use of PCNB began in 1959 with the issuance of a registration for technical PCNB (USEPA 1981a). Estimates of domestic consumption are readily available only for the period 1979 to 1984. Consumption appears to have steadily declined over this period with consumption in 1979 estimated to be 5.2 to 6.7 million pounds and consumption in 1984 estimated to be 2.0 to 2.5 million pounds (USEPA 1980b, USEPA 1981a, Torla 1985, Bomberger et al. 1985). A comparison of PCNB uses in 1979 to uses in 1983-1984 is presented in Table 3-4.

The limited amount of data on domestic production and exports/imports of PCNB during the 1970s also indicate that domestic consumption of PCNB may have peaked during the late 1970s. Estimates of domestic production are available for 1971 (3.0 million pounds), 1972 (2.6 million pounds), 1979 (8.0 million pounds), and 1980 (4.8 to 5.5 million pounds (USEPA 1977, Mumma and Lawless 1975, USEPA 1980b, USEPA 1981a). Estimates of imports over the period 1967 to 1979 were relatively low (never more than 0.14 million pounds) (Caswell 1979), and exports are estimated to have ranged from 25 percent of production (circa 1977) (USEPA 1977) to between 8 and 17 percent of production in 1980 (USEPA 1981a).

PCNB is not currently being manufactured in the U.S. The sole domestic manufacturer over the period 1959 to 1984, Olin Corporation, recently ceased PCNB production and sold its PCNB registrations to Uniroyal Corporation, which has not resumed manufacturing PCNB. PCNB is imported into the U.S. now primarily from Mexico.

HCB Releases - Prior to 1984, Olin Corporation manufactured PCNB at two sites, McIntosh, Alabama, and Leland, Mississippi. Wastes generated at these sites containing HCB are believed to have been landfilled (Brooks and Hunt 1984).

Table 3-4. Comparison of PCNB Uses, 1979 vs 1983-84

Site	Percent of total use		Acres treated (1,000)		Percent of site acreage treated		Treatment rate (lb/acre)
	1979	1983-84	1979	1983-84	1979	1983-84	
Agricultural uses							
Grains (total)	2.5	9	3,750	4,180	3.6	-	NA
- Barley	-	4	-	3,000	-	4	NA
- Oats	-	4	-	958	-	12	NA
- Wheat	-	1	-	222	-	1	NA
Crucifers (total)	4-7	15	16.4	15.6	9	-	NA
- Seedbeds	-	1	-	0.9	-	-	NA
- Broccoli	-	<1	-	0.2	-	<1	11-15
- Brussels sprouts	-	1	-	0.7	-	13	11-15
- Cabbage	-	9	-	10.5	-	11	11-15
- Cauliflower	-	4	-	3.3	-	8	NA
Beans	<1	1	25.2	13	8	4	1-2[a]
Cotton-soil	36-51	17	2,178	400	17	4	NA
Cotton-seed	2.5	2	2,725	1,000	21	7	NA
Garlic	<1	2	1.8	1.8	19	14	10-17[a]
Peanuts	24	5	142	11	9	<1	35
Peppers & tomatoes	<1	5	4.4	9.5	2.4	-	7.0
- Peppers	-	-	-	-	-	12	7.5[a]
- Tomatoes	-	-	-	-	-	1	7.5[a]
Rice	2	2	833	800	36	29	NA
Soybeans	4-6	14	7,000	7,100	12	10	NA
Sugarbeets	<1	<1	8.3	-	<1	-	NA
Nonagricultural uses							
Ornamentals	<1	6	0.98	-	-	-	NA
Turf	10-13	18	16.8	14.7	-	-	11

NA - Not available.

[a] This rate is per 14,500 linear feet; the actual area of application depends on the width of the crop row.

S( ): Torla (1985), USEPA (1981a), Pelletier (1985).

Assuming a current annual domestic use of 2.5 million pounds of PCNB and assuming an HCB contaminant level of 0.5 percent (5,000 ppm) yields an estimated release to the environment of 12,500 pounds (5,675 kg) of HCB annually from PCNB use. When the allowable contaminant level drops to 0.1 percent (in 1988), the HCB release will be 2,500 pounds (1,135 kg).

(2) Chlorothalonil

Uses - Chlorothalonil is a fungicide registered for use on a wide range of agricultural crops and for use on horticultural crops, on golf courses and residential turf, and in paint as a preservative. It is applied primarily as a spray to foliage by various types of ground and aerial application equipment (Pelletier 1985). Table 3-5 summarizes the estimated uses of chlorothalonil in 1979 and 1981. Peanuts and tomatoes are the major agricultural use sites of chlorothalonil, accounting for 56 and 12 percent, respectively, of the estimated total chlorothalonil used in 1981. Other major use sites are golf courses and paint which represented 10 and 5 percent, respectively, of the total U.S. use in 1981.

Major geographic areas of use for peanuts are Georgia and Alabama; smaller amounts are used in Virginia, North Carolina, Texas, and Oklahoma. A Major area of use for tomatoes is California, followed by tomato producing areas in the North/Northeast and South (primarily Florida). Figure 3-3 provides a map of geographic areas of probable concentrated use of chlorothalonil.

HCB Level in Chlorothalonil - A registration standard was issued by EPA for chlorothalonil in September 1984. HCB was recognized as a manufacturing impurity and, as a result, the standard requires that chlorothalonil not contain more than 0.05 percent (500 ppm) of HCB (Duffy 1985). The HCB level in chlorothalonil prior to the issuance of the 1984 standard is not known.

Production/Consumption of Chlorothalonil - The first registration for a chlorothalonil product was issued in 1966 (personal communication between Greg Schweer, Office of Toxic Substances, USEPA and H.M. Jacoby, Office of Pesticide Programs, USEPA, on January 24, 1986). Domestic production of chlorothalonil apparently did not begin until about 1977. Available information indicates that until 1970 little chlorothalonil was imported. From about 1970 to 1977, annual imports averaged about 3 million pounds, from 0.9 million pounds imported in 1970 to 3.6 million pounds imported in 1977 (Eckerman 1982, Caswell 1979).

Table 3-5. Domestic Chlorothalonil Usage by Site, 1979 and 1981

Site	Use in 1979 (1,000 lbs)	Percent of total use 1979	Percent of total use 1981	Acres treated in 1981 (1,000)	Regional usage	Tolerance (ppm)	Treatment rate (lb/acre)
Agricultural uses							
Broccoli	134	2	<1		None specifically	5	1.5
Celery	327	4	1		None specifically	15	0.8 - 2.3
Cucumbers	16	<1	2		None specifically	5	1.5
Onions	54	1	3		None specifically	0.5 (dry)	1.2 - 2.3
Peanuts	5,000-7,000	66	56	952	AL,GA,VA,NC,TX,OK	0.3	0.8 - 1.2
Potatoes	400-500	5	4	106	West,N.East,MI	0.1	0.8 - 1.2
Tomatoes	700-900	9	12	119	CA,N/N.East,FL	5	1.4 - 2.3
Other sites[a]	~300	~3-4	~4-7		None specifically	[a]	NA
Nonagricultural uses							
Golf courses	661	7	10		None specifically	-	NA
Paint preservative	350	4	5		None specifically	-	2.4 - 11.5[b]
Residential turf	43	<1	<1		None specifically	-	NA
Horticultural crops	7	<1	<1		None specifically	-	NA
Total	7,990-10,320	100	100				

NA - Not available.

[a] All other sites account for 1 percent or less, individually, of the total annual usage. EPA has established tolerances for 27 other raw agricultural commodities (40 CFR 180.275) and for citrus oil (21 CFR 193.84).

[b] This rate is in pounds per 100 gallons.

Sources: Eckerman (1982); Schutte (1984); Pelletier (1985); 40 CFR 180.275.

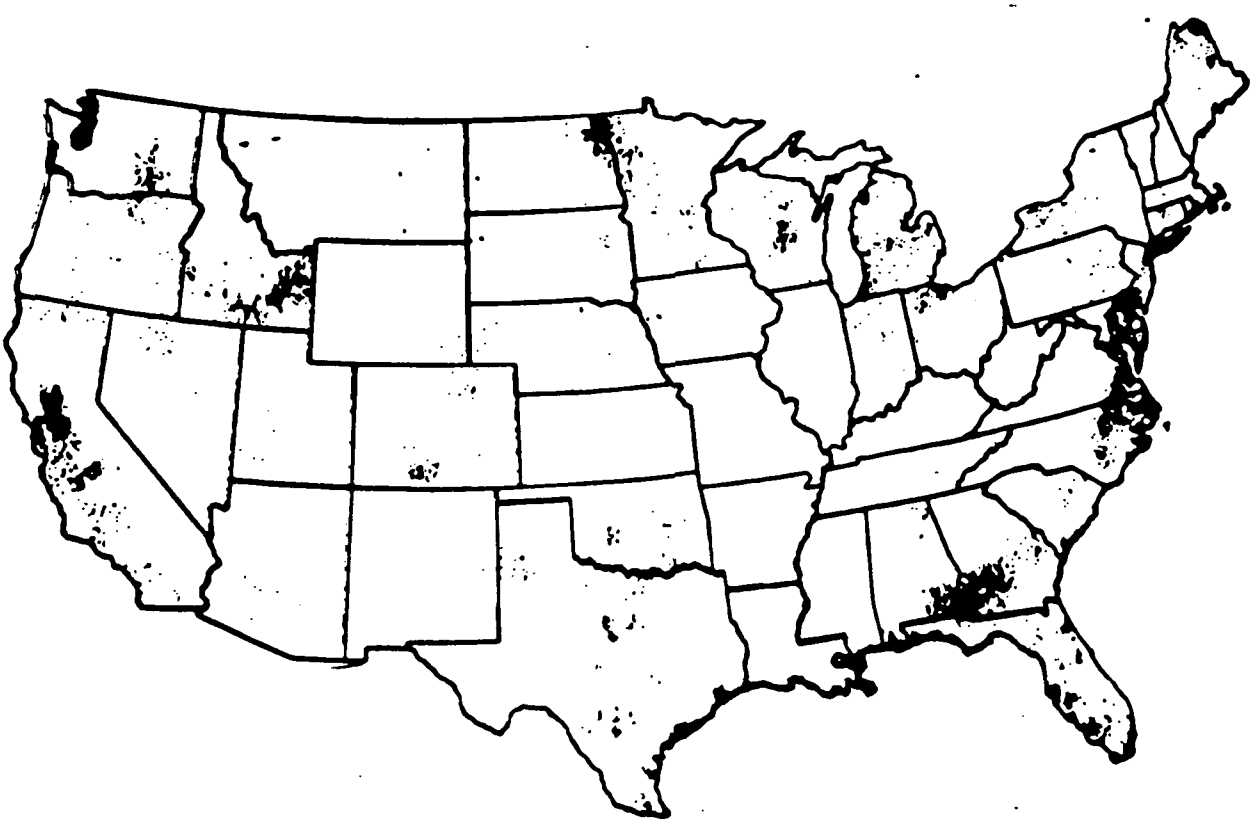


Figure 3-3. Major geographic areas of chlorothalonil use [constructed by overlaying maps from the 1978 Census of Agriculture (U.S. Department of Commerce 1982) of "crop acreage harvested" for the following crops using the regional chlorothalonil usage information in Table 3-4: cucumbers, peanuts, potatoes, and tomatoes. Maps were not available for other crop uses. Darkened areas of map indicate usage areas].

In 1979, an estimated 28 to 31 million pounds of chlorothalonil were produced domestically. Domestic use had increased in 1979 to an estimated 8 to 11 million pounds annually with 20 million pounds being exported (Eckerman 1982). An estimated 7.5 million pounds were used domestically in 1981 (Schutte 1984). Since 1977, imports have been negligible (Eckerman 1982).

HCB Releases - Chlorothalonil is currently manufactured at one site, Greens Bayou, Texas, by SDS Biotech. Manufacturing wastes containing HCB are apparently disposed of at an offsite landfill (Brooks and Hunt 1984).

Assuming a current annual domestic use of 7.5 million pounds of chlorothalonil and assuming an HCB contaminant level of 0.05 percent (500 ppm) yields an estimated release of 3,750 pounds (1,700 kg) of HCB annually from chlorothalonil use.

(3) Dimethyl Tetrachloroterephthalate (DCPA)

Uses - DCPA (trade name Dacthal) is a preemergence herbicide for treatment of mineral soils that grow vegetables, nursery stocks, and field crops, and for treatment of foliage of turf and strawberries (Pelletier 1985). There are 192 registered products containing DCPA, the majority of which are formulated and packaged for the home and garden markets (Holtorf 1984). Table 3-6 summarizes the approximate annual usage of DCPA during the period 1980 to 1983. There do not appear to be any specific regional areas of use.

HCB Levels in DCPA - Since 1973, the maximum allowed HCB content of technical grade DCPA has been 0.3 percent (3,000 ppm) (Mumma and Lawless 1975, Eilrich 1986). An agreement between the sole manufacturer and EPA requires that 0.3 percent be the maximum HCB level (Duffy 1985). Prior to 1973, the HCB content of DCPA was reported by the manufacturer to be as high as 10 percent (Mumma and Lawless 1975).

Production/Consumption of DCPA - Only limited information on domestic production and use are available. The first registration standard for a DCPA product was issued in 1962. The sole manufacturer reported production volumes of 2 and 4 million pounds in 1972 and 1974, respectively (Mumma and Lawless 1975). Recent estimates of domestic use, for the period 1980 to 1983, are about 4.8 million pounds per year (Holtorf 1984).

HCB Releases - DCPA is currently manufactured at one site, Greens Bayou, Texas, by SDS Biotech. Manufacturing wastes containing HCB are apparently disposed of at an offsite landfill (Brooks and Hunt 1984).

Table 3-6. Domestic DCPA (Dacthal) Usage by Site, 1980-1983

Site	Annual use (1,000 lbs)	Percent of total use	Percent of site acreage treated	Regional usage
Home and garden[a]	2,000-2,500	50-55	Unknown	None specifically
Commercial vegetable production[b]	1,750-2,250	40-45	Unknown	None specifically
Field crops[b,c]	<200	5	Very minor	None specifically
Total	~4,500	100		

[a] Includes all turfgrass usage.
[b] EPA has established tolerances in or on 45 raw agricultural commodities (40 CFR 180.155).
[c] Primarily cotton.

Source: Holtorf (1984).

Assuming a current annual domestic use of 4.8 million pounds of DCPA and assuming an HCB contaminant level of 0.3 percent (3,000 ppm) yields an estimated release of 14,400 pounds (6,540 kg) of HCB annually from DCPA use.

(4) Picloram

Uses - Picloram is a herbicide used for controlling broad-leaved plants and conifers in grasses. It is applied both aerially and directly to soil (Thomson 1979). Table 3-7 summarizes the current (circa 1981) uses of picloram. It does not appear to be widely used on pastures, rangelands, or wheat (one percent or less of potential site acreage is treated), and the extent of its use for forest site preparation and on rights-of-way is unknown.

HCB Levels in Picloram - A registration standard for picloram was issued in March 1985 that specifies a maximum HCB content of 0.02 percent (200 ppm). No information is readily available on historical HCB contaminant levels.

Production/Consumption of Picloram - Picloram was first introduced in 1963. Production and use estimates are readily available only for 1981. In 1981, an estimated 2.2 to 2.9 million pounds of picloram were domestically produced. An estimated 0.8 to 1.0 million pounds were used domestically with the remainder exported (Schutte 1982).

HCB Releases - Picloram is currently manufactured at one site, Freeport, Texas, by Dow Chemical, USA. Manufacturing wastes containing HCB are apparently disposed of by incineration (PEI 1985).

Assuming a current annual domestic use of 1 million pounds of picloram and assuming an HCB contaminant level of 0.02 percent (200 ppm) yields an estimated of 200 pounds (91 kg) of HCB annually from picloram use.

(5) Pentachlorophenol (PCP)

Uses - PCP is registered for use as an insecticide, fungicide, herbicide, algicide, and disinfectant and as an antifouling ingredient in paint. In general, about 80 percent of PCP is used for wood preservation. Most of the remaining PCP is used as (1) a fungicide in the manufacture of a variety of industrial products such as leather and paper and (2) a biocide in cooling towers (USEPA 1981b, Beloian 1985). Except as a seed treatment (for nonfood uses), PCP has not been registered for use on any food or feed crop. EPA has established no tolerances or exemptions from tolerances for PCP.

Table 3-7. Domestic Picloram Usage by Site, 1981

Site	Use (1,000 lbs)	Percent of total use	Percent of site acreage treated	Regional usage	Tolerances[a] (ppm)
Agricultural uses					
Pasture	145-180	18	0.5-1.0	East	-
Rangeland	208-260	26	0.05-0.1	West	-
Forest site preparation	160-200	20	Unknown	Southeast	-
Wheat	8-10	1	0.5-1.0	Great Plains	0.5 (grain)
Nonagricultural uses					
Rights-of-way	280-350	35	Unknown	None specifically	
Total use	800-1,000	100			

[a] EPA has established tolerances for 42 raw agricultural commodities, 30 of which are meat or poultry products/byproducts (40 CFR 180.292).

Source: Schutte (1982); 40 CFR 180.292.

HCB Level in PCP - According to USEPA (1981b), commercial PCP generally contains 100 ppm of HCB. Cleveland et al. (1982) measured 150 ppm of HCB in Dowicide EC-7 (91 percent PCP) and 56 ppm of HCB in a composite of the standard production technical grade PCP produced by three PCP manufacturing companies.

Production/Consumption of PCP - Domestic production of PCP was about 50 million pounds in 1977 (USEPA 1981b) and 74 million pounds in 1982 (Beloian 1985).

HCB Releases - PCP is currently manufactured at two sites: Tacoma, Washington, by Reichhold Chemicals, Inc. and in Wichita, Kansas, by Vulcan Materials Company. The Tacoma site apparently disposes of HCB-containing wastes in a landfill, and the Wichita plant uses incineration as the disposal method.

Assuming a current annual domestic use of 74 million pounds of PCP and assuming an HCB contaminant level of 0.01 percent (100 ppm) yields an estimated release of 7,400 pounds (3,360 kg) of HCB annually from PCP use. Much of this HCB would be expected to be incorporated into treated wood from which it would slowly be released.

3.2.2 Other Inadvertent Production of HCB

Besides the production of pesticides, HCB can be inadvertently produced during a number of manufacturing processes. Examples include chlorinated solvents such as perchloroethylene and other important industrial chemicals such as chlorine and hexachlorocyclopentadiene. The names, locations, and products of those facilities that are currently producing chemicals whose manufacture is known to generate HCB are given in Table 3-8; the locations of these facilities are depicted graphically in Figure 3-4. Note that the pesticide manufacturers have been included in Table 3-8 and Figure 3-4 for continuity. Discussions of HCB production during the manufacture of chlorinated solvents and other industrial chemicals are presented separately below.

(1) Chlorinated Solvents - During the production of chlorinated solvents, HCB is formed in the processing steps of thermal chlorination, oxychlorination, and pyrolysis operations. The vast majority of HCB produced during the manufacture of chlorinated solvents is found in the heavy ends or still bottoms from distillation or product purification. HCB has also been detected at low concentrations in wastewaters, spent catalysts, spent caustics, off-specification products, and wastewater sludges (OSW 1985). Since HCB is easily separated during purification steps, the product contains essentially no HCB. It has been estimated

Table 3-8. Locations of Facilities Currently Producing Chemicals Whose Manufacture Is Known to Generate HCB, 1985[a,b,c]

Map number[d]	Company	Plant location	Product(s)	HCB waste disposal[h]
1	Diamond Shamrock Corp.	Deer Park, TX	Perc	I
2	Dow Chemical, USA	Freeport, TX[e]	Perc; TCE; carbon tet; picloram	I
3	Dow Chemical, USA	Pittsburg, CA	Perc; carbon tet	I
4	Dow Chemical, USA	Plaquemine, LA	Perc; carbon tet	I
5	E.I. duPont De Nemours & Co, Inc.	Corpus Christie, TX[f]	Perc; carbon tet	U
6	KemaNord, Inc.	Columbus, MS	Chlorine	U
7	Kerr McGee Chemical Corp.	Hamilton, MS	Chlorine	U
8	Kerr McGee Chemical Corp.	Henderson, NV	Chlorine	U
9	LCP Chemical & Plastics, Inc.	Moundsville, WV	Carbon tet	L
10	Monsanto Company	Sauget, IL	Dichlorobenzenes	U
11	Occidental Chemical Corp.	Montague, MI	HEXA	U
12	Occidental Chemical Corp.	Tacoma, WA	Chlorine	U
13	Occidental Chemical Corp.	Taft, LA	Chlorine	U
14	PPG Industries, Inc.	Lake Charles, LA	Perc; TCE	I
15	PPG Industries, Inc.	Natrium, WV	Mono-,Di-,Tri-,Tetra-chlorobenzenes	U
16	Reichhold Chemicals, Inc.	Tacoma, WA	PCP	U
17	SDS Biotech Corp.	Greens Bayou, TX	Dacthal; chlorothalonil	L
18	Southland Corp.	Great Meadows, NJ	Trichlorobenzene	U
19	Standard Chlorine Chemical Co.	Delaware City, DE	Mono-,Di-,Tri-, chlorobenzenes	U
20	Stauffer Chemical Co.	LeMoyne, AL[g]	Carbon tet	-
21	Velsicol Chemical Co.	Memphis, TN	Hexa	L
22	Vulcan Materials Co.	Geismar, LA	Perc; carbon tet	I
23	Vulcan Materials Co.	Wichita, KS	Perc; carbon tet; PCP	I

[a] Chemicals whose manufacture is known to generate HCB include: perchloroethylene (perc), trichloroethylene (TCE), carbon tetrachloride (carbon tet), chlorine, pentachlorophenol (PCP), hexachlorocyclopentadiene (HEXA), picloram, dacthal, chlorothalonil, and chlorinated benzenes.

[b] Facility locations obtained from SRI Directory of Chemical Producers (1975 to 1985) for manufacturers of organic compounds and from Callison and Ferguson (1985) for chlorine manufacturers.

[c] With the following exceptions, all listed facilities produced the listed organic chemicals continuously from at least 1975 to 1985:

- SDS Biotech Corp - chlorothalonil (1977-1985)
- Southland Corp - trichlorobenzene (1981-1985).

[d] Map number refers to location on Figures 4-2.

[e] According to USEPA (1985a), Dow Chemical was to stop production of perchlorethylene and carbon tetrachloride at its Freeport facility in 1984.

[f] According to USEPA (1985a), Dow Chemical was to stop production of perchloroethylene at its Corpus Christi facility in 1985.

[g] The carbon tetrachloride manufacturing process used at this facility is not expected to generate HCB (Bomberger et al. 1985).

[h] These data are from Brooks and Hunt (1984); no detailed attempt was made to examine waste disposal practices at those facilities not examined by Brooks and Hunt (1984). I is incineration, U is unkown, and L is landfill.

[a]See Table 3-8 for site locations.

Figure 3-4. Locations of facilities currently producing chemicals whose manufacture is known to generate HCB[a].

that approximately 75 percent of the total amount of HCB produced in this country occurs as a byproduct in the production of three commercially important chlorinated solvents: carbon tetrachloride, trichloroethylene, and tetrachloroethylene (OSW 1985). Much smaller quantities of HCB are produced during the manufacture of chlorinated benzenes. Other chlorinated solvents (e.g., 1,1,1-trichlorethane) generate insignificant quantities of HCB during their production (Bomberger et al. 1985). Table 3-9 summarizes the estimated quantities of HCB in the wastes and estimated HCB releases to the environment resulting from the manufacture of carbon tetrachloride, trichloroethylene, perchloroethylene, and chlorinated benzenes. A listing of the specific facilities that manufacture these compounds was shown in Table 3-8, and they were depicted graphically in Figure 3-4.

(2) Other Important Industrial Compounds - Besides chlorinated solvents and pesticides, the manufacture of several other industrial compounds also produces HCB. A list of compounds that are either suspected or known to produce HCB during their manufacture is presented in Table 3-10.

Most of the HCB produced during these processes will end up in product purification residues such as still bottoms or heavy ends from distillation; very little is expected in the product. OSW (1985) has estimated that the total amount of HCB in miscellaneous solid waste from chlorinated organic compound manufacture is 2.6 kkg/yr. This is a worst case estimate since it includes some small miscellaneous waste streams from chlorinated solvent production. Nearly all of these wastes will be incinerated; less than 0.5 percent is landfilled (OSW 1985).

Small amounts may also end up in the process wastewaters. OSW (1985) estimated that 2.88 kkg/yr may be in process wastewaters from chlorinated organic production, before treatment. A summary of the estimated HCB releases from other chlorinated organic compound production is presented in Table 3-11. As can be seen in this table, estimated HCB releases from these processes are much less than the estimated releases from chlorinated solvent manufacture.

3.3 Miscellaneous Sources

Several miscellaneous sources of HCB have been identified in the literature. Three of the most important are municipal incineration, wastewater and process water chlorination, and releases from landfills that are known to contain HCB. A discussion of each of these sources is presented below.

Table 3-9. Estimated Quantities of HCB Produced During the Manufacture of Carbon Tetrachloride, Trichloroethylene, Perchloroethylene, and Chlorinated Benzenes

Chlorinated solvent	Production volume (10^6 kg)	Amount of heavy ends and still bottoms produced[a] (10^6 kg)	Concentration of HCB in waste[b] (%)	Amount of HCB produced (10^6 kg)	Releases		
					Air[c] (kg)	Land[c] (kg)	Water (kg)
Carbon tetrachloride	323.4[d]	12.9	10 - 65	1.3 - 8.4	1,260 - 8,220	26,000 - 168,000	NA
Trichloroethylene	65.7[e]	2.6	5 - 20	0.1 - 0.5	130 - 510	2,000 - 10,000	NA
Perchloroethylene	260.0[d]	10.4	20 - 25	2.1 - 2.6	2,040 - 2,540	42,000 - 52,000	NA
Chlorinated benzenes	173.2[f]	NA	-[f]	<0.01[g]	<0.01	<0.1	NA
Total	-	-	-	3.5 - 11.5	3,430 - 11,270	70,000 - 230,000	~0-41[h]

NA - Not available.

[a]This is based on a generation rate of 0.04 kg of bottoms per kg of product (OSW 1985).
[b]The range was selected from Environ (1985) and OSW (1985).
[c]Releases were estimated based on the assumption that 98 percent of the wastes are incinerated and 2 percent are landfilled (OSW 1985). It was assumed the destruction efficiency of the incinerator is 99.9 percent.
[d]USITC (1985). These are 1984 production volume estimates.
[e]USEPA (1985b). These are 1983 production volume estimates.
[f]Environ (1985) has reported that HCB is present in wastes from the production of chlorinated benzenes; however, no concentrations were given.
[g]OSW (1985).
[h]This was based on monitoring data of wastewater discharges from industrial facilities that produce carbon tetrachloride, trichloroethylene, or perchloroethylene (Li et al. 1976) and on wastewater discharges reported in the IFD file that are known to produce carbon tetrachloride, trichloroethylene, and perchloroethylene. It was assumed all process water at the facilities was contaminated with 7.1 ug/l of HCB, and the total volume of process water was estimated based on the total production volume. The 41 kg is a worst case estimate.

Table 3-10. Nonpesticide Compounds Whose Manufacture Is Known to Produce or Suspected of Producing HCB

Compounds Known to Produce HCB[a,b]

1. Chlorobenzenes
2. Chlorinated aliphatic hydrocarbons (carbon tetrachloride, Perchloroethylene, trichloroethylene)
3. Benzyl chloride[c]
4. Ethyl chloride[d]
5. Phthalic anhydride[e]
6. Chlorine
7. Hexachlorocyclopentadiene (HEX)
8. Phthalocyanine dyes and pigments

Compounds Whose Manufacture Is Suspected of Producing HCB[b]

1. Phosgene
2. Toluene diisocyanate (TDI)
3. Cyanuric chloride
4. 2-chloro-1,3-butadiene (chloroprene)
5. Titanium dioxide
6. 1,1,2-Trichloro-1,1,1-trifluoroethane (fluorocarbon 113)
7. Chlorophenols
8. Tetrachlorophthalic anhydride
9. Polychlorinated naphthalenes
10. Chlorinated paraffins
11. 1,2-Dichloroethane (ethylene dichloride) and vinyl chloride monomer (VCM)
12. Azo dyes
13. Polyethylene and polypropylene
14. 3-Chloropropane (allyl chloride) and dichloropropenes

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[a]Environ (1985).
[b]Bomberger et al. (1985).
[c]Environ (1985) reports HCB levels of 0.4-0.6 percent in still bottoms.
[d]Environ (1985) reports HCB levels of 0-18 percent in the heavy ends.
[e]USEPA (1983b).

Table 3-11. Estimated HCB Releases Resulting from the Production of Other Organic Chemicals

Waste stream	Estimated total quantity of HCB-containing waste[a] (kkg/yr)	Estimated total quantity of HCB generated[a] (kkg/yr)	Estimated releases (kg)		
			Air	Land	Water
Miscellaneous solid wastes	16,670	2.60	2.6[b]	13[c]	-
Process wastewater	41,980	2.88	d	d	29[e]

[a]OSW (1985)

[b]Assuming that 99.5 percent of the waste is incinerated (OSW 1985) and that the incinerator destruction and removal efficiency is 99.9 percent.

[c]Assuming 0.5 percent is landfilled.

[d]Negligible amount, although it could not be quantified.

[e]Assuming biological treatment and >99 percent removal (USEPA 1983a).

3.3.1 Municipal Waste Incineration

HCB has been detected in both the flue gas and fly ash resulting from municipal waste incineration. Most of this HCB is produced during the combustion process, although small amounts may be contained in the municipal waste.

Combustion in an incinerator is a very complicated process that depends on such factors as the reactor type, residence time, reactor temperatures, and feed materials. The destruction efficiency and the amount of inadvertent waste compounds produced during incineration depend on the relationships among the operating variables and the constituents found in the feed material (i.e., the municipal waste). To produce HCB during combustion, however, the waste products must contain chlorine. In the case of municipal wastes, several commonly found materials contain chlorine (e.g., plastics, paper products).

Estimated Emissions

Actual HCB emission levels from municipal incineration are very site-specific and thus cannot be generically estimated. However, based on monitoring data and previous studies, a rough range of the total HCB releases from all municipal incinerators in the U.S. can be approximated. This range has been estimated to be 57-454 kg/yr. The assumptions used to derive this result are given below:

1. It is assumed that 18,500 metric tons of municipal waste are disposed of by incineration facilities in the U.S. per day for 300 days per year; this is 5.55×10^{-6} metric tons per year (Bomberger et al. 1985)

2. It has been reported that one metric ton of municipal waste produces 30 kg of fly ash and 7000 m^3 of cleaned stack gases which contain 0.66 kg of particulates (Bomberger et al. 1985)

3. Several studies have estimated HCB concentrations in incinerator flue gasses, the range of concentrations is approximately 1.4 to 11 ug/m^3 (Tiernan et al. 1983, Samuelsson and Lindskog 1983, Janssens et al. 1982). Furthermore, Janssens et al. (1982) estimated that 93.8 percent of the total HCB released is in the vapor phase, 5.4 percent is in particulates <0.5 um, and 0.8 percent is in particulates >0.5 um.

4. Estimated amount of flue gas produced: 5.55×10^6 kg/yr x 7000 $m^3/kg = 3.89 \times 10^{10}$ m^3/yr.

5. Estimated quantity of HCB In the flue gas: 3.89×10^{10} m^3/yr x 1.4-11 $ug/m^3/yr$ = 54 - 428 kg.

6. Estimated quantities in the flyash:

Light particulates	= 54 - 428 kg/yr x 0.008
	= 0.43 - 3.4 kg/yr.
Heavy particulates	= 54 - 428 kg/yr x 0.054
	= 2.9 - 23 kg/yr.
Total particulates	= 3.3 - 26 kg/yr.

7. Total estimated HCB releases from municipal incinerators is 57 to 454 kg/yr.

3.3.2 Wastewater and Process Water Chlorination

Numerous processes require chlorination of aqueous streams. Examples include drinking water disinfection, wastewater treatment, chlorination of cooling water, and chlorination of wood pulp. These processes have the potential to produce HCB since it is known that the chlorination of aqueous streams containing dissolved organics produces chlorinated organic materials.

However, a review of the literature by Bomberger et al. (1985) found very little convincing data to support this hypothesis. The most rigorous reaction conditions possible in water appear to be insufficient for complete chlorination of the benzene ring. Extensive studies of contaminant levels in industrial wastewater failed to detect HCB, except at plants where HCB was produced as a byproduct. Some evidence does indicate that HCB was produced during the treatment of cooling water, since it has been detected in fish from a power plant cooling pond (Bomberger et al. 1985). In addition, it has been detected in the treated wastewater from three electric power plants (See Table 5-34). However, the evidence is not conclusive because the contaminations could have occurred from the deposition of HCB released to the atmosphere from the power plant boilers or it could have been introduced as a contaminant in pentachlorophenol, which has been used in cooling water as a biocide. Finally, no direct evidence was found in the literature of HCB contamination in pulp and paper wastewater discharges in the United States (Bomberger et al. 1985).

Since HCB is so stable (see Section 4), it is also important to consider HCB that had been previously disposed of in landfills as a potential current source. Because of low costs and convenience, landfilling was the predominant final waste management practice in the 1970s (OSW 1985). Therefore, a considerable amount of HCB may be present

in landfills, which could potentially volatilize or very slowly leach into ground water or run off into surface waters. Table 3-12 presents a list of the Superfund and potential Superfund sites that are known to contain HCB; their locations are depicted graphically in Figure 3-5. Most of the sites are located in Michigan, Indiana, Ohio, Pennsylvania, and Louisiana. No quantitative HCB release data are available for these historical sites.

3.4 Previous Sources

Since HCB is very persistent in the environment, it is important to examine historical source data on HCB. Table 3-13 lists the locations of facilities that previously produced chemicals during the period from 1975 to 1984 whose manufacture is known to generate HCB; the locations of these facilities are graphically depicted in Figure 3-6. As can be seen, the locations of these facilities are concentrated in New Jersey, western New York, along the Mississippi and Ohio Rivers, and in the Northwest.

As noted in Section 3.1.2, the manufacture of chlorine using oil-impregnated graphite electrodes may generate HCB as a byproduct. Although some facilities still use this manufacturing technique, most have switched to metal anodes over the last 15 years or have shut down. Consequently, a historical perpective on this source of HCB is important. Table 3-14 lists chlorine manufacturing sites where oil-impregnated graphite electrodes are used or have been used, and Figure 3-7 graphically depicts their locations. Most of the facilities are located along the Mississippi drainage basin or in the Northwest.

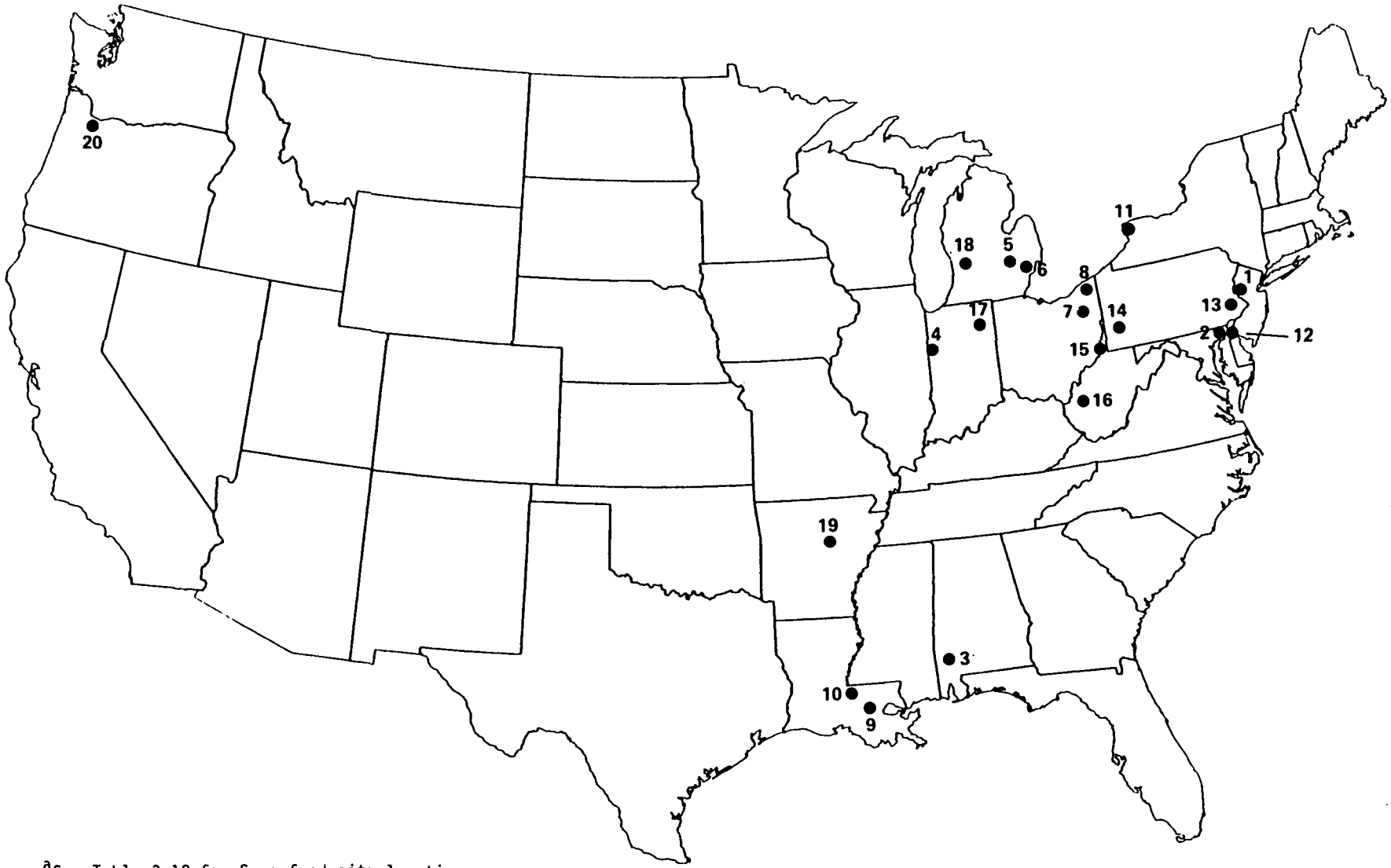
Table 3-12. Superfund and Potential Superfund Sites Known to Contain HCB

Map no.	Site	Location	Media[a]
	National Priority List site		
1	Myers Property	Franklin Twp., NJ	Solids
2	Maryland Sand & Gravel	Elkton, MD	Water
3	Olin Corp.	McIntosh, AL	Water
4	Calumet Container	Hammond, IN	Water
5	Berlin & Farro	Swartz Creek, MI	Solids
6	Liquid Disposal, Inc.	Utica, MI	Solids
7	Summit National Liquid	Deerfield, OH	N/A
8	Old Mill Site	Rock Creek, OH	Water/sediments
9	Cleve-Reber	Sorrento, LA	Solids/water
10	Petro-Processors	Scotlandville, LA	Solids
	Removal sites		
11	Love Canal (Black Creek)[b]	Niagara Falls, NY	Water/solids/air
12	Sealand Ltd.	Mt. Pleasant, DE	Leaking tank
	Potential Superfund sites		
13	Alchem Products	Ambler, PA	Water
14	Jefferson Twp Drum Site	Jefferson Twp., PA	N/A
15	PPG Indust., Inc.	Natrium, WV	Solids
16	South Charleston Landfill	S. Charleston, WV	Solids
17	Parrot Road Dump	New Haven, IN	Water
18	Approved Industrial Removal	Wyoming, MI	Water
19	Jacksonville City Landfill	Jacksonville, AR	Solids
20	Stauffer Chemical Co.	Portland, OR	Solids

[a] Media in which HCB was detected; N/A indicates not available.

[b] HCB has been detected in solids and air at other Love Canal area sites including 102 N. Street, Bloody Run Creek, and Gill Creek.

Source: Fields (1984).



[a]See Table 3-12 for Superfund site locations.

Figure 3-5. Superfund and potential Superfund sites known to contain HCB[a]

Table 3-13. Locations of Facilities That Previously Produced Chemicals Whose Manufacture Is Known to Generate HCB (1975 - 1984)[a,b,c]

Map number	Company name	Plant location	Products	Years of manufacture (1975-84)
1	Allied Chemical Corp.	Syracuse, NY	Mono-,Dichlorobenzenes	1975-79
2.	Champion Intnl. Corp.	Canton, NC	Chlorine	e
3.	Dover Chemical Corp.	Dover, OH	PCP; HCB	1975-77
4.	Dow Chemical, U.S.A.	Midland, MI	Mono-,Di-,Tri-,Tetrachlorobenzenes; PCP	1975-83
5.	Eastman Kodak Co.	Rochester, NY	Dichlorobenzene	1975-77
6.	Ethyl Corporation	Baton Rouge, LA	Perc; TCE	1975-82
7.	FMC Corporation	S. Charleston, WV	Carbon tet	1975-79
8.	Formosa Plastics Corp.	Baton Rouge, LA	Chlorine	g
9.	Guardian Chem. Corp.	Hauppauge, NY	Dichlorobenzenes	1975-76
10.	Hummel Chem. Co., Inc.	S. Plainfield, NJ	HCB	1975-77
11.	ICC Industries, Inc.	Niagara Falls, NY	Mono-,Dichlorobenzenes	1976-78
12.	Montrose Chem. Corp. of CA	Henderson, NV	Mono-,Dichlorobenzenes	1975-82
13.	Occidental Chem. Corp.	Niagara Falls, NY	Hexa; Mono-,Di-,Tri-, Tetrachlorobenzenes	1975-82 (Hexa) 1975 (Chloro-benzenes)
14.	Occidental Chem. Corp.	Taft, LA	Perc; TCE	1975-78
15.	Olin Corporation	McIntosh, AL	PCNB	1975-83
16.	Olin Corporation	Leland, MS	PCNB	1978-84

Table 3-13. (continued)

Map number	Company name	Plant location	Products	Years of manufacture (1975-84)
17.	Pennwalt Corporation	Calvert City, KY	Chlorine	d
18.	Pennwalt Corporation	Portland, OR	Chlorine	d
19.	Pennwalt Corporation	Tacoma, WA	Chlorine	d
20.	PPG Industries, Inc.	Lake Charles, LA	Chlorine	g
21.	PPG Industries, Inc.	Natrium, WV	Chlorine	g
22.	Sobin Chems. Inc.	Newark, NJ	Trichlorobenzenes	1975
23.	Solvent Chem. Co., Inc.	Niagara Falls, NY	Mono-,Di-,Trichlorobenzenes	1975-77
24.	Solvent Chem. Co., Inc.	Malden, MA	Mono-,Di-,Trichlorobenzenes	1975-76
25.	Sanford Chem. Co.	Houston, TX	PCP	1975
26.	Standard Chlorine Chem.	Kearny, NJ	Di,-Trichlorobenzenes	1975-77
27.	Stauffer Chem. Co.	Louisville, KY	Carbon tet; perc	1975-84
28.	Stauffer Chem. Co.	Niagara Falls, NY	Carbon tet	1975-76
29.	Vertac, Inc.	Jacksonville, AR	Tetrachlorobenzene	1975-77
30.	Vulcan Materials Corp.	Denver City, TX	Chlorine	f

[a] Chemicals whose manufacture is known to generate HCB include: perchloroethylene (perc), trichloroethylene (TCE), carbon tetrachloride (carbon tet), chlorine, pentachlorophenol (PCP), hexachlorocyclopentadiene (hexa), chlorinated benzenes, and pentachloronitrobenzene (PCNB).

[b] Facility locations obtained from the SRI Directory of Chemical Producers for the years 1975 to 1984 and from Callison and Ferguson (1985) (for chlorine manufacturers).

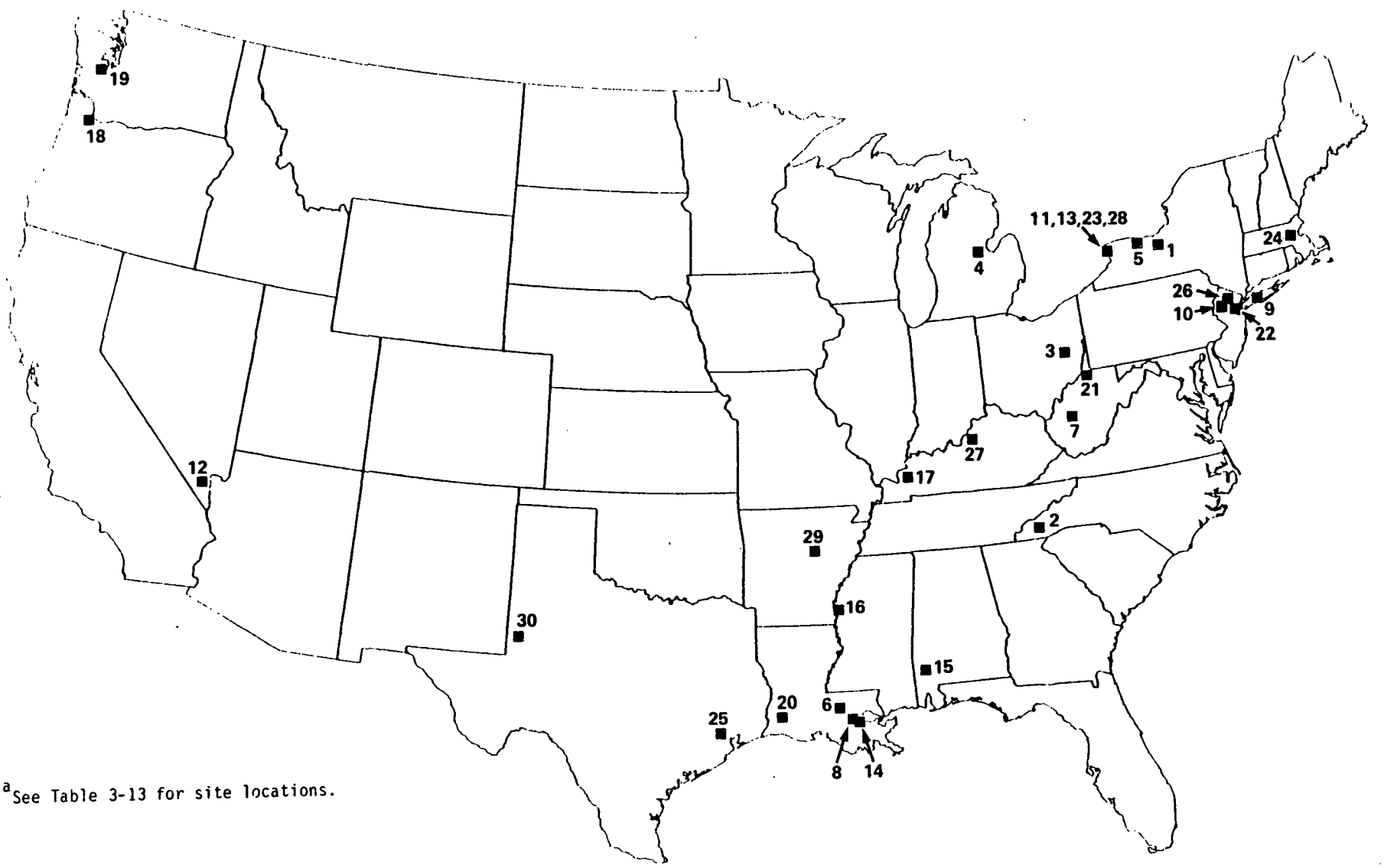
[c] The list of previous chlorine manufacturers may not be all-inclusive.

[d] Converted to non-HCB-generating metal anodes in early to mid 1970s.

[e] Plant shut down in 1984.

[f] Plant shut down in 1983.

[g] Converted to non-HCB-generating metal anodes between 1980 and 1984.



[a]See Table 3-13 for site locations.

Figure 3-6. Locations of facilities that previously produced chemicals whose manufacture is known to generate HCB[a].

Table 3-14. Chlorine Manufacturing Sites Where Oil-Impregnated Graphite Electrodes Are Used or Have Been Used[a]

Map number	Company name	Plant location	Use status[b]
1	Kema Nord, Inc.	Columbus, MS	1
2	Kerr-McGee Chem. Corp.	Hamilton, MS	1
3	Kerr-McGee Chem. Corp.	Henderson, NV	1
4	Pennwwalt Corp.	Calvert City, KY	2
5	Pennwalt Corp.	Portland, OR	2
6	Pennwalt Corp	Tacoma, WA	2
7	Occidental Chem. Corp.	Taft, LA	1
8	Occidental Chem. Corp	Tacoma, WA	1
9	Champion Intnl. Corp.	Canton, NC	3
10	Vulcan Materials Corp.	Denver City, TX	4
11	Formosa Plastics Corp.	Baton Rouge, LA	5
12	PPG Industries, Inc.	Lake Charles, LA	5
13	PPG Industries, Inc.	Natrium, WV	5

[a]Sites identified in Callison and Ferguson (1985). Not all sites that have been converted from graphite to metal anodes were identified.

[b]Use status codes:
1 = current user.
2 = converted to metal anodes in early to mid 1970s.
3 = plant shut down in 1984.
4 = plant shut down in 1983.
5 = converted to metal anodes between 1980 and 1984.

Source: Callison and Ferguson (1985).

[a]See Table 3-14 for site locations.

Figure 3-7. Chlorine manufacturing sites where oil-impregnated graphite electrodes are used or have been used[a].

3.5 REFERENCES

Beloian A. 1985. HCB project. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs. Memo from A Beloian to SL Duffy, February 20, 1985.

Blackwood TR, Sipes TG. 1979. Status assessment of toxic chemicals: hexachlorobenzene. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. EPA-600/2-79-210g.

Bomberger DC, Bruckman EM, Frierman M, Jimenez A, Nelson C, Doeltz MK, Mould CB. 1985. Hexachlorobenzene: Chemistry of formation and identified sources. Washington DC: U.S. Environmental Protection Agency EPA Contract No. 68-02-3976.

Brooks GW, Hunt GE. 1984. Source assessment for hexachlorobenzene. Research Triangle Park, NC: U.S. Environmental Protection Agency. EPA Contract No. 68-02-3818.

Callison SL, Ferguson FA. 1985. Evaluation of the extent of HCB contamination that may result from the use of graphite electrodes to produce chlorine and sodium chlorate via electroysis. Menlo Park, California: SRI International. EPA Contract No. 68-02-3976.

Caswell RL. 1979. Pesticide handbook - entoma 1979-1980. College Park, MD: Entomological Society of America.

Cleveland L, Buckler DR, Mayer FL, Branson DR. 1982. Toxicity of three preparations of pentachlorophenol to fathead minnows - a comparative study. Environmental Toxic. and Chemical (1): 205-212

Devine K. 1982. Preliminary quantitative usage analysis of hexachlorobenzene. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

Dime RA. 1982. Environmental fate of hexachlorobenzene. Ph.D Dissertation, University Microfilms International. Order No. 82-20134.

Duffy SL. 1985. Registration Division report on pesticides containing HCB. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

Eckerman DE. 1982. Preliminary quantitative usage analysis of chlorothalonil. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

Eilrich GL. 1986. Letter from GL Eilrich (SDS Biotech) to DP Rall (National Toxiology Program) February 24, 1986.

Environ Corp. 1985. Characterization of waste streams listed in 40 CFR Section 261 waste profiles. Draft report. Washington, DC: Office of Solid Waste, U.S. Environmental Protection Agency.

Farm Chemicals Handbook. 1986. Farm chemicals handbook. Willoughby, OH: Meister Publishing Co.

Fields T. 1984. Emergency Response Division, U.S. Environmental Protection Agency. Information on hexachlorobenzene (HCB) at Superfund and potential Superfund sites. Memorandum to Arnold M. Edelman, Chairman, Hexachlorobenzene Task Group, Washington, DC: U.S. Environmental Protection Agency.

Holtorf RC. 1984. Preliminary quantitative usage analysis of dimethyl tetrachloroterephthalate. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

Janssens J, Van Vaeck L, Schepens D, and Adams F. 1982. Qualitative and quantitative analysis of emissions of a municipal incineration installation. Comm Eur. Commun. EUR 7624: 28-38.

Li RT, Spigarelli JL, Going JE. 1976. Sampling and analysis of selected toxic substances, task 1A - hexachlorobenzene. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA-560/6-76-001 (PB 253-794).

Mould DB, Doelty MK, Burchmann EM. 1985. Classification of pesticides based on the potential for occurrence of hexachlorobenzene as an impurity and/or byproduct. Washington, DC: U.S. Environmental Protection Agency. EPA Contract No. 68-02-3976.

Mumma CE, Lawless EW. 1975. Survey of industrial processing data, Task I - hexachlorobenzene, pollution from chlorocarbon processes. Washington, DC: U.S. Environmental Protection Agency. EPA Contract No. 68-01-2105. EPA 560/3-75-003.

OSW. 1985. OSW report on HCB source and management assessment. Washington, DC: U.S. Environmental Protection Agency.

PEI Associates, Inc. 1985. Sources of hexachlorobenzene.
Pelletier EN 1983. Report on Agricultural pesticide containing HCB. Washington, DC: U.S. EPA, memo from EN Pelletier to H Testillman (EPA) October 18, 1983.

Pelletier EN. 1985. Fungicidal uses of HCB and other fungicides possibly containing HCB. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs. Memo from EN Pelletier to P Tobin, February 11, 1985.

Quinlivan SM, Ghasseni M, Shanty M. 1976. Survey of methods used to control wastes containing hexachlorobenzene. Washington, DC: U.S. Environmental Protection Agency. PB 253 051.

Samuelsson U, Lindskog A. 1983. Chlorinated compounds in emissions from municipal incinerators. Chemsophere. 12(4/5): 665-668.

Schutte WD. 1982. Preliminary quantitative usage analysis of picloram. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

Schutte WD. 1984. Current benefits review of chlorothalonil. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

Thomson WT. 1979. Agricultural chemicals - Book II - herbicide. Fresno, CA: Thompson Publications.

Tiernan TO, Taylor ML, Garrett GF et al. 1983. Chlorobenzodoxins, chlorodibenzofurans and related compounds in the effluents from combustion processors. Chemosphere, 12(4/5): 595-606.

Tobin PS. (unpublished). HPLC analysis of pesticides, TiO2, and chlorinated organic solvents for HCB content. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances.

Torla RF. 1985. Preliminary quantitative usage analysis of PCNB. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

U.S. Department of Commerce. 1982. 1978 census of agriculture. Graphic Summary. Vol. 5, Part 1. Washington, DC: U.S. Dept. of Commerce, Bureau of the Census.

USEPA. 1977. Pentachloronitrobenzene (PCNB): Position document 1. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

USEPA. 1980a. Development document for the aluminum forming point source category. Draft report. Washington, DC: U.S. Environmental Protection Agency, Effluent Guidelines Division, Office of Water and Waste Management.

USEPA. 1980b. Preliminary quantitative usage analysis of PCNB. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

USEPA. 1981a. Preliminary benefit analysis of pentachloronitrobenzene (PCNB). Draft, Washington, DC: U.S. Environmental Protection Agency, Office of Pesticide Programs.

USEPA. 1981b. Creosote, inorganic arsenials, pentachlorophenol - Position Document No. 2/3. Washington, DC: U.S. Environmental Protection Agency Office of Pesticide Programs NTIS-PB82-229956.

USEPA. 1983a. Development document for final effluent limitations and standards for the rubber manufacturing point source category. Draft report. Washington, DC: U.S. Environmental Protection Agency, Effluent Guidelines Division, Office of Water.

USEPA. 1983b. Development document for proposed effluent limitations guidelines and new source performance standards for the organic chemicals and plastics and sythetic fibers industry. Washington, DC: Effluent Guidelines Division, U.S. Environmental Protection Agency.

USEPA. 1983c Treatability manual - industrial description. Volumes I and II. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development.

USEPA. 1985a. Survey of perchloroethylene emission sources. Research Triangle Park, NC: Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. EPA-450/3-85-017.

USEPA. 1985b. Survey of trichloroethylene emission sources. Research Triangle Park, NC: Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. EPA-450/3-85-021.

USITC. 1985. Synthetic organic chemicals, United States production and sales, 1984. Washington, DC: United States International Trade Commission. USITC Publication 1745.

4. ENVIRONMENTAL FATE AND TRANSPORT

4.1 Summary

Hexachlorobenzene (HCB) exhibits high environmental mobility because of its volatility from both water and landfills. Once in the troposphere, HCB appears resistant to photodegradation and can be removed by precipitation/dry deposition or possible transport to the stratosphere. Slow photolytic dechlorination, however, appears to be the principal mechanism for degradation in surface water. Although HCB has been reported to be immobile in soil after agricultural application, it can be transported in runoff water as an adsorbate on suspended particles. In addition, transport by volatilization from the soil occurs readily if the sorption capacity of the soil for HCB has been exceeded, as it would be in a landfill. Volatilization from landfills is considered to be the principal path for removal of HCB deposited therein as a waste. Seepage into ground water is not considered to be a likely problem. Some plants can accumulate HCB to an extent greater than the soil HCB content in their roots and also in portions of the plant growing closest to the soil. Bioaccumulation also occurs in aquatic animals, but unchanged HCB can be depurated when the source of pollution is removed. Microorganisms appear incapable of degrading HCB, but both terrestrial and aquatic plants and animals are reported to effect slow biotransformation of HCB to several compounds, primarily chlorinated phenols and thiophenols. A summary of the environmental fate and transport of HCB is presented in Table 4-1.

4.2 Photodegradation

Hexachlorobenzene absorbs ultraviolet radiation with wavelengths <310 nm, and it has an absorption maximum at 290 nm (Dime 1982). Nonetheless, photodegradation of HCB as a vapor, or as an adsorbate on silica gel, has been reported as not occurring when HCB was irradiated at 290 nm for six days (Parlar 1978). Production of HCl and CO_2 was observable, however, when HCB was irradiated at 230 nm. Freitag et al. (1984) also reported radiation above 290 nm to be ineffective with regard to photodegradation of HCB adsorbed on silica gel. HCB is probably photochemically stable in the troposphere (Parlar 1978), but degradation in the stratosphere by photodissociation due to the action of the shorter wavelength, higher ultraviolet light present there may be a mechanism for atmospheric destruction.

When a dilute solution of HCB in distilled water or 2 percent aqueous methanol was irradiated in a laboratory photoreactor or in summer sunlight, half-lives of 284 $\pm$ 62 and 293 $\pm$ 163 hours were observed,

Table 4-1. Summary of Environmental Fate and Transport of Hexachlorobenzene

Environmental process	Summary statement	Confidence of data
Photolysis	Slow photolytic dechlorination in the aquatic environment is probably a major mechanism for degradation. Photodissociation of any HCB that diffuses upward to the stratosphere should occur because of the action of shorter wavelength, higher energy ultraviolet light.	Medium
Oxidation	Not a significant process.	High
Hydrolysis	Not a significant process.	High
Volatilization	Volatilization from water and landfills is a major transport path for removal of hexachlorobenzene through atmospheric dissipation.	High
Sorption	Hexachlorobenzene is strongly sorbed to soil and sediments and is not considered a danger to ground water; it can, however, be transported on particulates in runoff and surface water.	High
Bioaccumulation	Bioaccumulation occurs in plants and animals but can also be followed by depuration of the unchanged compound from aquatic animals.	High
Biodegradation	Biodegradation occurs slowly and to a small extent in both plants and animals, but microorganisms do not degrade hexachlorobenzene.	High

respectively (Dime 1982). The presence of 2 percent acetone increased the photolysis rate to give a half-life in sunlight of 69 ± 17 hours. Approximately 15 percent of the reacted HCB was converted to pentachlorobenzene; tetrachlorobenzene also was tentatively identified as a product. Water can apparently serve as a hydrogen donor in the photolytic dechlorination of hexachlorobenzene. Although photolysis in the aquatic environment would be slow, it still makes (in comparison to other processes) a major contribution to the global disposition of this pollutant (Dime 1982).

4.3 Oxidation and Hydrolysis

Hexachlorobenzene is both thermally and hydrolytically stable under conditions of the ambient environment (Callahan et al. 1979). It is resistant to oxidation except under extreme conditions and reacts with strong caustic solutions only above 130°C (Leoni and D'Arca 1976).

4.4 Volatilization

Dime (1982) has studied the rate of HCB volatilization from water both in the presence and in the absence of a surface slick of dodecanol. The surface slick did not retard volatilization. At 26°C, the half-lives were 5 hours and 5.7 hours in the presence and absence of the dodecanol, respectively. This compares well with the predicted half-life of 8 hours given by calculations (Callahan et al. 1979) according to the method of MacKay and Leinonen (1975).

In laboratory experiments designed to simulate conditions of an outdoor pond, Sugiura et al. (1984) determined the half-life for volatilization of dilute aqueous HCB to be 10 hours. This value (as well as other laboratory-determined transport data) was successfully used in the aquatic model of Neely and Blau (1976) to predict environmental concentrations in an experimental outdoor pond. Schauerte et al. (1982) found that the half-life for disappearance of HCB from an experimental pond was 1.3 days. This half-life, however, was attributed to the interaction of volatilization with sorption by suspended particulates and biota. Volatilization from surface water is thus an important transport pathway for HCB, but competition of volatilization with sorption and bioaccumulation probably governs the short-term fate of HCB.

Volatilization is considered to be the principal transport path for removal of HCB deposited as a waste in landfills (Farmer et al. 1980a, Dime 1982). Covers of compacted wet soil and plastic sheeting reduce this volatilization but do not eliminate it (Farmer et al. 1980b). However, some of the hexachlorobenzene that is introduced into soil

during agricultural use or deposited with rain and airborne particulates is probably not volatilized readily (Beck and Hansen 1974, Ausmus et al. 1979, Scheunert et al. 1983). Beall (1976) followed the persistence of HCB applied aerially (equivalent to 10 ppm in the top 5 cm of soil) to a simulated pasture in a greenhouse for 19 months. Twenty hours after application, the top 2 cm of soil contained 5.6 ppm HCB. Concentrations found after 0.5, 1, 6.5, 12, and 19 months were 45.2 percent, 24.4 percent, 7.9 percent, 4.7 percent, and 3.4 percent of the initial 5.6 ppm. Concentrations in the 2 to 4 cm layer averaged 0.11 ppm with no significant change throughout the 19 months. Although it appears that HCB volatilizes readily from the soil surface but not the soil itself, an alternative explanation is that the sorption capacity of the soil for HCB had been exceeded in the top 2 cm during the initial application. After 19 months, the concentration (0.19 ppm) in the top 2 cm approached the concentration (0.11 ppm) in the 2 to 4 cm layer. Under these circumstances, sorption of HCB to the soil appears to compete successfully with volatilization . In another example, loss of applied HCB from a pine forest soil by both volatilization and leaching was less than 0.1 percent over a period of 21 days (Ausmus et al. 1979). Hexachlorobenzene apparently volatilizes from soil only when the sorptive capacity of the soil has been exceeded, as it would be, for example, in a saturated area of a landfill.

4.5 Sorption

Hexachlorobenzene has been reported to be very immobile in soil and sediment with respect to partitioning with water (Griffin and Chou 1981, Scheunert et al. 1983). In experiments conducted by Karickhoff and Morris (1985), it was observed that sorption of HCB to natural aquatic sediments required extended time periods for complete equilibration. This sorption consisted of two components, an easily reversible one requiring only a few hours to achieve an equilibrated exchange of HCB with the water and a slow sorption that was not easily reversible and required several weeks before equilibration occurred. Karickhoff and Morris (1985) interpreted this observation as the consequence of sorption of HCB to the surface of sediment particles (rapid exchange) and diffusion of HCB within the interior of sediment particles (slow exchange).

HCB can be transported from soil as an adsorbate on finely divided particulates in runoff water (Ausmus et al. 1979). Presumably, HCB can also be transported in surface water as an adsorbate on suspended particulates. Transport on suspended particulates is probably responsible for the contamination of Lake Ontario water and sediments by hexachlorobenzene that was originally present in the Niagara River

(Durham and Oliver 1983). Dime (1982) considers transport to the ocean on finely divided particulates in runoff water and surface water to be a minor but relevant mechanism for removal of HCB from the continental environment. Leaching of HCB into ground water is not considered to be a serious problem (Dime 1982, Scheunert et al. 1983, Griffin and Chou 1981).

4.6 Bioaccumulation

A much more detailed review of the literature (than is presented in this subsection) concerning HCB bioconcentration, bioaccumulation, and depuration in aquatic and terrestrial organisms is presented in USEPA (1986).

4.6.1 Terrestrial Plants

Some plants can accumulate HCB to an extent greater than the soil HCB content in their roots and also in portions of the plant growing closest to the soil (Smelt and Leistra 1974, Scheunert et al. 1983). Smelt (1976) observed that the accumulation of HCB in leafy vegetables appears to occur principally at the growth stage of seedlings. The roots of plants generally accumulate higher concentrations of soil-applied organic chemicals than do aerial plant parts. This observation has been demonstrated for HCB with sugar beets, carrots, turnips, wheat, and pasture grass (Smelt and Leistra 1974, Scheunert et al. 1983). When HCB is applied directly to wheat seeds before they are planted, all parts of the plant accumulate more of the chemical than they do through uptake of soil-applied HCB (Scheunert et al. 1983). In a terrestrial laboratory ecosystem, studied by Gile and Gillett (1979), the initial accumulation (<20 ppm) of HCB in plants was followed by a decrease in concentration. Table 4-2 summarizes data on the accumulation of HCB by terrestrial plants. The agricultural product that accumulates the greatest amount of HCB is the carrot root.

There are some contradictory studies that report the accumulation of HCB in leafy plants to be higher than that listed in Table 4-2 (Dejonckheere et al. 1976, 1981; Hafner 1981). These studies, however, were conducted in greenhouses or forcing beds where HCB, evaporating from the soil, would not be rapidly dissipated to the atmosphere. Hafner (1981) points out that temperature and moisture are higher in the soils of greenhouses and forcing beds than they would be in the soil of an open field. Under these indoor conditions, HCB could more easily volatilize from the soil and condense on the cooler surfaces provided by the leafy plants. Thus, higher amounts of HCB would be associated with the plant leaves than could normally be absorbed from soil.

Table 4-2. Accumulation of HCB in Terrestrial Plants of Agricultural Relevance

Plant	HCB (mg/kg)		Plant/Soil Ratio
	Plant	Soil	
Potato tubers[a]	0.11	0.22	0.50
	0.20	0.40	0.50
	0.13	0.18	0.72
	0.017	0.027	0.63
	0.10	0.16	0.63
Potato[b]	0.013	0.091	0.14
	0.046	0.059	0.78
	0.011	0.082	0.13
	0.031	0.064	0.48
	0.045	0.060	0.75
Tulip bulbs[a]	0.12	0.30	0.40
	0.065	0.10	0.65
	<0.002	0.003	<0.67
	0.16	0.10	1.60
Shallot bulbs[a]	0.056	0.12	0.47
Sugar-beet bulbs[a]	0.095	0.41	0.23
	0.012	0.027	0.44
	0.027	0.056	0.48
	0.010	0.024	0.42
Sugar-beet crowns[a]	0.014	0.41	0.03
	0.004	0.027	0.15
	0.005	0.056	0.09
	0.002	0.024	0.08
Sugar-beet leaves[a]	0.022	0.41	0.05
	0.010	0.027	0.37
	0.017	0.056	0.30
	0.006	0.024	0.25
Grass roots[a]	0.81[c]	0.09	9.0
	0.56[c]	0.14	4.0
	0.19[c]	0.07	2.7
	0.76[d]	0.033	23
	0.039[d]	0.001	39

Table 4-2. (Continued)

Plant	HCB (mg/kg)		Plant/Soil Ratio
	Plant	Soil	
Grass blades[a]	0.22[c]	0.09	2.4
(lower 5 cm)	0.20[c]	0.14	1.4
	0.10[c]	0.07	1.4
Grass blades[a]	0.028[c]	0.09	0.31
(above 5 cm)	0.042[c]	0.14	0.30
	0.016[c]	0.07	0.23
	0.003[d]	0.033	0.09
	0.011[d]	0.12	0.09
Wheat roots[e]	-	-	2.59
Wheat low stems	-	-	0.390
Wheat straw	-	-	0.083
Wheat husks	-	-	0.009
Wheat grain	-	-	0.003
Wheat (total)	-	-	0.214
Carrot roots[a]	1.25	0.065	19
	0.48	0.04	12
Carrot leaves[a]	0.44	0.065	6.8
	0.25	0.04	6.2
Turnip roots[a]	0.18	0.062	2.9
Turnip leaves[a]	0.014	0.062	0.23
Lettuce[f]	0.02[g]	1.4[h]	0.014
	0.03[i]	0.20[h]	0.15
	0.04[j]	1.5[h]	0.027
	<0.02[k]	1.1[h]	<0.018
	<0.02[l]	0.90[h]	<0.022
	0.04[i]	0.30[m]	0.13
	0.05[j]	3.2[m]	0.016
	0.02[k]	1.9[m]	0.010
	<0.02[l]	1.5[m]	<0.013

Table 4-2. (Continued)

Plant	HCB (mg/kg) Plant	Soil	Plant/Soil Ratio
Lettuce[f] (continued)	0.05[j]	5.4[n]	0.009
	0.02[k]	2.8[n]	0.007
	<0.02[l]	2.5[n]	<0.008
	<0.02[k]	4.0[p]	<0.005
	0.02[l]	2.5[p]	<0.008
	<0.02[l]	5.1[q]	<0.004

a Agricultural crops taken from fields that had been treated three to five times with HCB-containing pentachloronitrobenzene. HCB content is based on dry sample mass (Smelt and Leistra 1974).

b Each entry represents 8 to 10 samples from a specific county in Western Slovakia. It was not stated whether tubers or whole plants were analyzed, and it is uncertain whether values are based on wet mass or dry mass (Uhnak et al. 1979).

c Young grass (1 or 2 months after sowing).

d One-year old pasture.

e Relative content of HCB-^{14}C in summer wheat (wet mass) in relation to soil (air dried) residues at 0 to 20 cm depth (Scheunert et al. 1983).

f Botrilex dust (20% pentachloronitrobenzene plus HCB impurity) applied as 34 g of dust/m^2 to greenhouse soil and raked in before planting lettuce (Paxton and Purser 1982).

g Harvested at approximate 2 g fresh mass of plants.

h One application of Botrilex dust.

i Second crop: 45 days after first harvest.

j Third crop: 90 days after first harvest.

k Fourth crop: 135 days after first harvest.

l Fifth crop: 225 days after first harvest.

m Two applications of Botrilex dust.

n Three applications of Botrilex dust.

p Four applications of Botrilex dust.

q Five applications of Botrilex dust.

4.6.2 Aquatic Biota

The bioaccumulation potential of hexachlorobenzene has been studied using radiotracer techniques in model aquatic ecosystems, and in all studies, HCB has been found to be bioaccumulated and resistant to biodegradation (Callahan et al. 1979). Isensee et al. (1976) observed that for any specific concentration of added HCB, higher food chain organisms (such as snails and mosquito larva) always contained 1.5 to 2 times more hexachlorobenzene than lower food chain organisms such as algae and daphnids. Furthermore, the highest food chain organism (catfish) in the study accumulated 10 times more hexachlorobenzene than did any other organisms.

Dime (1982) has found that freshwater clams (i.e., Corbicula malensensis) rapidly remove HCB from water with steady state being reached in 50 to 60 hours. His study also showed that clams can depurate the unchanged chemical, although much more slowly, when they are placed in an uncontaminated environment (half-life for elimination was longer than 30 hours).

Freitag et al. (1984) have observed bioaccumulation factors for HCB in algae and fish to be 24,800 and 2,600, respectively. The algae were exposed to a constant concentration of 0.05 mg/l for 24 hours, and the fish were exposed at the same concentration of HCB for 3 days. Freitag et al. (1984) state that their bioaccumulation factor for HCB in fish is a nonequilibrium value. Using a computerized kinetic approach, Kosian et al. (1981) estimated that a steady-state bioconcentration factor for HCB in freshwater fish should be 52,000. Based on this bioconcentration factor, Niimi and Cho (1981) have interpreted the relative HCB levels found in the water of Lake Ontario, the lake's Coho salmon, and the smelt and alewives in the salmon stomachs to mean that bioaccumulation rather than bioconcentration has been the more important process in determining the contamination levels of HCB in these fish.

Schauerte et al. (1982) investigated the distribution of hexachlorobenzene in the water, sediment, and biota of a group of experimental ponds. After addition of HCB to the pond, the half-life for its decrease in the water was 1.3 days. Concomitantly, there was a rapid build-up of HCB in the sediment and biota followed by a slow decrease in the sediment over a period of three years and a somewhat more rapid decrease in the biota. These observations can be rationalized by recognizing that, although the initial rates of sorption and bioaccumulation of HCB successfully compete with its rate of volatilization from water, equilibrium partitioning of HCB eventually decreases the HCB concentration in sediment and biota as the HCB

volatilizes from the water. In this case, the rate of volatilization is much faster than the rate of desorption or depuration. Therefore, the sediment and aquatic biota can act not only as a short-term sink for HCB, but also as a long-term source.

4.7 Biodegradation

Although hexachlorobenzene is degraded very slowly by both plants and animals (Callahan et al. 1979, Scheunert et al. 1983, Sandermann et al. 1984), microorganisms appear to have little or no ability to degrade this compound (Isensee et al. 1976, Tabak et al. 1981). Aerobic mixed cultures showed no tendency to acclimate themselves to hexachlorobenzene after three weekly subcultures (Tabak et al. 1981). Soil biotic activity (measured by CO_2 efflux) was inhibited by HCB at all doses in a pine forest microcosm (Ausmus et al. 1979). Scheunert et al. (1983) concluded, after studying the fate of ^{14}C-labeled HCB that had been applied to wheat field microcosms under outdoor conditions, that HCB metabolism in soil is negligible. Isensee et al. (1976) have reported that no loss of HCB occurred in soil cultures under aerobic or anaerobic conditions over a period of one year. Freitag et al. (1984) were not able to detect any degradation of HCB in activated sludge.

Most of the hexachlorobenzene taken up by terrestrial plants appears to become incorporated into high molecular weight organic matter, nonextractable with water or organic solvents. This nonextractable material amounts to 70 percent of absorbed HCB in wheat grain (Scheunert et al. 1983). Sufficient extractable material was available only for identification of the major metabolite, pentachlorothiophenol. This metabolite represents less than 1 percent of the HCB absorbed by the wheat plant. Smaller amounts of unidentified compounds and unchanged HCB constituted the remainder of the extractable material.

It is generally accepted that fish excrete accumulated hexachlorobenzene primarily unchanged, at a rate related to its lipophilicity (Zitko 1977). In an aquatic microcosm to which ^{14}C-HCB had been added, Lu and Metcalf (1975) found that unchanged hexachlorobenzene accounted for 84 percent of the total radioactivity in the snail, 67 percent in the water flea, 65 percent in mosquito larva, and 64 percent in fish. Pentachlorophenol was identified in algae, in mosquito larvae, and in the aqueous phase as a degradation product. Lu and Metcalf (1975) considered HCB to be more easily biodegraded than DDT by an order of magnitude in aquatic ecosystems.

4.8 References

Ausmus BS, Kimbrough S, Jackson DR, Lindberg S. 1979. The behavior of hexachlorobenzene in pine forest microcosms: transport and effects on soil processes. Environ. Pollut. 20:103-111.

Beall ML, Jr. 1976. Persistence of aerially applied hexachlorobenzene on grass and soil. J. Environ. Qual. 5:367-369.

Beck J and Hansen KE. 1974. The degradation of quintozene, pentachlorobenzene, hexachlorobenzene, and pentachloroaniline in soil. Pestic. Sci. 5:41-48.

Callahan MA, Slimak MW, Gabel NW, May DP, Fowler CF et al. 1979. Water-related environmental fate of 129 priority pollutants. Vol. II. Washington, DC: Office of Water Planning and Standards, U.S. Environmental Protection Agency. EPA-440/4-79-029b.

Dejonckheere W, Steurbaut W, Kips RH. 1976. Residues of quintozene, its contaminants and metabolites in soil, lettuce, and witloof-chicory, Belgium - 1969-74. Pestic. Monit. J. 10:68-73.

Dejonckheere W, Steurbaut W, Kips RH. 1981. Problems caused by quintozene and hexachlorobenzene residues in lettuce and chicory cultivation. In: Decomposition of toxic and nontoxic organic compounds in soils. M.R. Overcash, ed. Ann Arbor, MI: Ann Arbor Science Publishers Inc., pp. 15-24.

Dime RA. 1982. Environmental fate of hexachlorobenzene. Ph. D. Dissertation, University Microfilms International. Order No. 82-20134.

Durham RW, Oliver BG. 1983. History of Lake Ontario contamination from the Niagara River by sediment radiodating and chlorinated hydrocarbon analysis. J. Great Lakes Res. 9:160-168.

Farmer WJ, Yang MS, Letey J, Spencer WF. 1980a. Hexachlorobenzene: its vapor pressure and vapor phase diffusion in soil. Soil Sci. Soc. Am. J. 44:676-680.

Farmer WJ et al. 1980b. Land disposal of hexachlorobenzene wastes. Controlling vapor movement in soil. Cincinnati, OH: Municipal Environmental Research Laboratory. EPA 600/2-80-119.

Freitag D, Lay JP, Korte F. 1984. Environmental Hazard Profile - Test results as related to structures and translation into the environment. In: QSAR in Environmental Toxicology. KLE Kaiser, et al. Netherlands: D. Reidel Publishing Co., pp.111-136.

Gile JD, Gillett JW. 1979. Fate of selected fungicides in a terrestrial laboratory ecosystem. J. Agric. Food Chem. 27:1159-1164

Griffin RA, Chou SFJ. 1981. Attenuation of polybrominated biphenyls and hexachlorobenzene by earth materials. Cincinnati, OH: Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. EPA-600/2-81-191.

Hafner M. 1981. Hexachlorobenzene residues in vegetables as a result of hexachlorobenzene adsorption from the soil. In: Decomposition of toxic and nontoxic organic compounds in soils. M.R. Overcash, ed. Ann Arbor, Michigan: Ann Arbor Science Publishers Inc. pp. 25-38.

Isensee AR, Holden ER, Woolson EA, Jones GE. 1976. Soil persistence and aquatic bioaccumulation potential of hexachlorobenzene. J. Agric. Food Chem. 24:1210-1214. (as quoted in Callahan et al. 1979).

Karickhoff SW, Morris KR. 1985. Sorption dyanamics of hydrophobic pollutants in sediment suspensions. Environ. Toxicol. Chem. 4:469-479.

Kosian P, Lemke A, Studders K, Veith G. 1981. The precision of the ASTM bioconcentration test. Washington, D.C.: U.S. Environmental Protection Agency. EPA 600/3-81-022, (NTIS PB81-168932).

Leoni V, D'Arca SU. 1973. Experimental data and critical review of the occurrence of HCB in the Italian environment. Sci. Total Environ. 5: 253-272.

Lu P, Metcalf RL. 1975. Environmental fate and biodegradability of benzene derivatives as studied in a model aquatic ecosystem. Environ. Health Perspect. 10:269-284. (as quoted in Callahan et al. 1979).

Mackay D, Leinonen PJ. 1975. Rate of evaporation of low-solubility contaminants from water bodies to atmosphere. Environ. Sci. Technol. 9:1178-1180.

Neely WB, Blau GE. 1976. The use of laboratory data to predict the distribution of chlorpyrifos in a fish pond. In: Khan MAQ (ed) Pesticides in aquatic environments. New York: Plenum Press. pp. 145-163. (as quoted in Sugiura et al. 1984).

Niimi AJ, Cho CY. 1981. Elimination of hexachlorobenzene (HCB) by rainbow trout (Salmo gairdneri) and the examination of its kinetics in Lake Ontario salmonids. Can. J. Fish. Aquat. Sci. 38:1350-1356.

Parlar H. 1978. Organochlorine compounds and their reactions in the atmosphere. Ecotox. Environ. Safety. 2:219-232. (as quoted in Dime 1982).

Paxton ARP, Purser D. 1982. Build-up and subsequent decline of residues of quintozene and hexachlorobenzene in lettuce in sequential crops. Pestic. Sci. 13:401-406.

Sandermann H., Jr., Scheel D, Trenck TVD. 1984. Use of plant cell cultures to study the metabolism of environmental chemicals. Ecotoxical Environ. Safety 8:167-182.

Schauerte W, Lay JP, Klein W, Korte F. 1982. Long-term fate of organochlorine xenobiotics in aquatic ecosystems. Ecotox. Environ. Safety. 6:560-569.

Scheunert I, Marra C, Viswanathan R, Klein W, Korte F. 1983. Fate of hexachlorobenzene - ^{14}C in wheat plants and soil under outdoor conditions. Chemosphere 12(7/8):843-858.

Smelt JH. 1976. The behavior of quintozene and hexachlorobenzene in the soil and their absorption into corps. Gewasbescherming. 7:49-58. (In German; translation)

Smelt JH, Leistra M. 1974. Hexachlorobenzene in soils and crops after soil treatment with pentachloronitrobenzene. Agric. Environ. 1:65-71.

Sugiura K, Masahiro A, Kaneko S, et al. 1984. Fate of 2,4,6-Trichlorophenol, pentachlorophenol, p-chlorobiphenyl, and hexachlorobenzene in an outdoor experimental pond: comparison between observations and predictions based on laboratory data. Arch. Environ. Contam. Toxicol. 13:745-758.

Tabak H, Quave SA, Mashni CI, Barth EF. 1981. Biodegradability studies with organic priority pollutant compounds. J. Water Pollut. Control Fed. 53:1503-1509.

Uhnak J. Mahelova E., Sackmauerova M, Tibenska M. 1979. Transfer of hexachlorobenzene and chlorinated insecticide residues from soil into plants. Agrochemia. 19:154-156. (In Russian; translation).

USEPA 1986. Environmental hazard assessment of hexachlorobenzene. Revised draft. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency.

Zitko V. 1977. Uptake and excretion of chlorinated and brominated hydrocarbons by fish. Fisheries and Marine Service Technical Report No. 737. Fisheries and Environmental Sciences Resource Branch, St. Andrews, New Brunswick. (as quoted in Callahan et al. 1979).

5. MONITORING DATA

This section presents the available monitoring data for HCB. In general, these data indicate that HCB is a ubiquitous pollutant; it has been detected in all environmental media (air, water, and land) and numerous types of living organisms, including insects, aquatic biota, and mammals.

The monitoring data in this section have been organized into five categories. Section 5.1 presents data from the diet studies conducted by the Food and Drug Administration. Section 5.2 has a summary of FDA's Surveillance and Compliance Monitoring Program. Section 5.3 contains information from the various studies performed by the Fish and Wildlife Service; data are presented for HCB residues found in fish, starlings, and ducks. In Section 5.4, the results of the analyses of HCB residues in livestock, as performed by the U.S. Department of Agriculture, are discussed. The National Human Adipose Tissue Survey results are detailed in Section 5.5. Section 5.6 contains a compilation of data from numerous HCB monitoring studies that have been reported in the open literature.

5.1 FDA Total Diet Study

5.1.1 Program Description

The Total Diet Study, initiated by the Food and Drug Administration (FDA) in the mid-1960s, consists of analyses of ready-to-eat foods for residues of pesticides, industrial chemicals, radionuclides, and essential element content. Analysis for HCB residues began in fiscal year (FY) 1970. The analytical methods used for this program are contained in FDA's Pesticide Analytical Manual (FDA 1971). Limits of quantitation for HCB are about ten times lower than those achieved in FDA's Surveillance and Compliance Monitoring Program (i.e., 0.001 ppm rather than 0.01 ppm).

Until mid-FY 1982, the food items collected and the food consumption values used in this program were based primarily on the 1965 USDA Household Food Consumption Survey. The prescribed balanced diets of three age groups in each of four geographic regions (see Figure 5-1) were analyzed: adults (16 to 19 year old males), infants (6 months old), and toddlers (2 years old). The Total Diet Studies for infants and toddlers were not initiated until FY 1975. To perform a total diet study, a 2- to 4-week food supply was collected in the form of market basket samples from several retail stores in one of the four regions. Generally, 20 adult and 10 infant/toddler market baskets were collected each year. The collected foods were separated into several classes of commodities (12 for the adult diet, 11 for the infant and toddler diets), prepared as for consumption, and the food items in each class were blended prior to analysis.

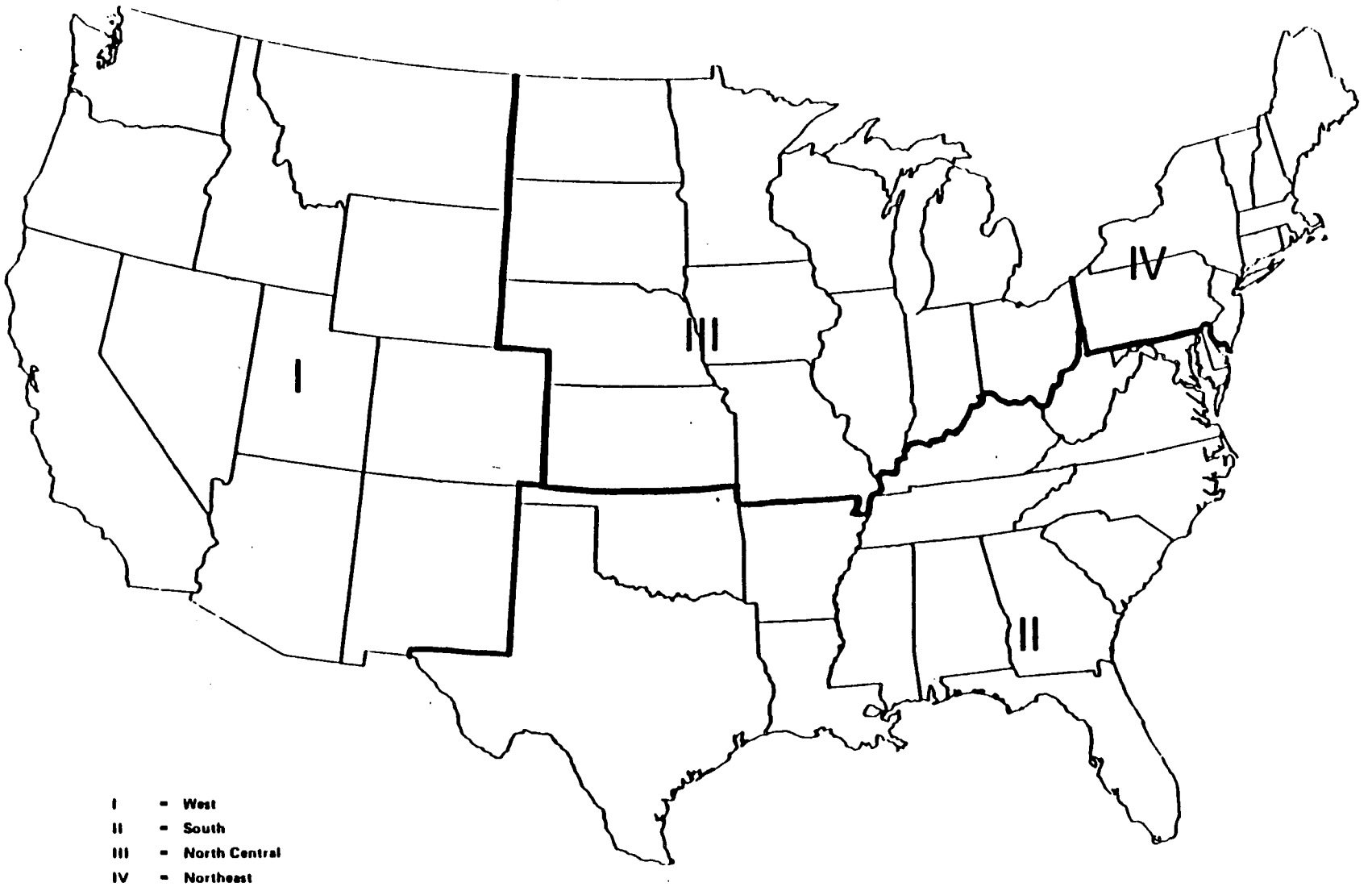


Figure 5-1. FDA total diet study regions.

Starting in mid-FY 1982, the Total Diet Study was revised to reflect more recent (1976-1980) food consumption data and to involve the analysis of 234 individual food items rather than food class composites. In addition, the dietary intakes of eight age-sex groups are calculated rather than three age groups. Four market baskets (one from each geographic region) are collected each year. Only preliminary data for the period 1982-1984 are available for this revised study.

5.1.2 Summary of Results

Based on the results of the Total Diet Studies, FDA estimated the average daily dietary intake of chemicals for each age group. Table 5-1 summarizes these estimated intakes for HCB, and Figure 5-2 graphically presents the estimates by year for each age group. There is an apparent rise in HCB intakes for toddlers and infants during the late 1970s followed by a decrease through the 1980s*.

Tables 5-2, 5-3, and 5-4 summarize the occurrence frequencies of HCB in each food class by year for each of the three age groups. It is evident from these tables that the dairy products; meat, fish, and poultry; and oils and fats** food classes account for the majority of the HCB detections. Figure 5-3 graphically depicts the percent of occurrence of HCB in each of these food classes by year for each of the three age groups. Similar to the increase in dietary intakes for infants and toddlers, a noticeable peak in the occurrence of HCB in the late 1970s followed by a decline is evident for each age group.

Figures 5-4 and 5-5 show the daily per person intake of HCB from the dairy products (combined milk and other dairy product food classes), meat/fish/poultry, and oils/fats food groups relative to the total daily intake for infants and toddlers, respectively. It is evident from the figures that for FY 1977-1980 dairy products generally account for the majority of HCB intake for toddlers and infants. The oils/fats food group accounts for the largest fraction of the intake in FY 1975, 1976, 1980, and 1981/1982. (Published information does not provide sufficient data to construct a similar figure for adult intake.)

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*The dramatic increase in intake for both toddlers and infants during 1977 was apparently caused by the detection of a relatively high concentration of HCB in one of the whole milk composites (3 ppb). Because of the high intake of milk by these age groups and the skewing effect of this one sample on the calculated avarage HCB level in milk, the calculated HCB intake may be unrealistically high.

**The oils/fats food class includes items such as peanut butter, mayonnaise, salad dressings, shortening, and margarine.

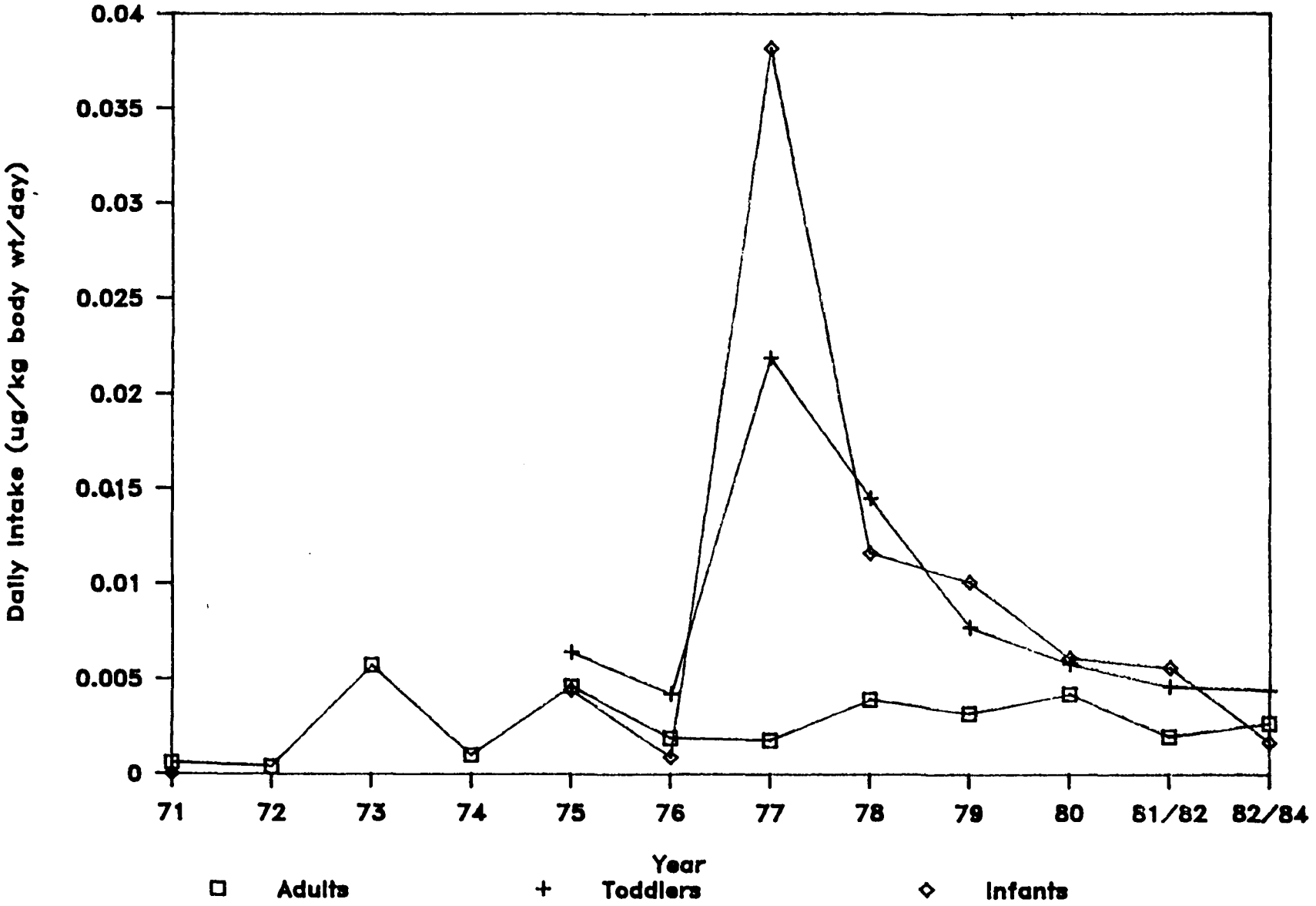
Table 5-1. FDA Total Diet Studies - Daily Dietary Intakes of HCB for Fiscal Years 1970 to 1982/84

Year	No. of market baskets	No. of cities	Estimated daily dietary intake of HCB (ug/kg body wt/day)[a, b] National average	Geographic regional averages West	North East	North Central	South
			Adults (16-19 year old males)				
1970	30	28					
1971	30	27	0.0006				
1972	35	32	0.0004				
1973	30	30	0.0057				
1974	30	30	0.0010				
1975	20	20	0.0046				
1976	20	20	0.0019	0.0035	0.0021	0.0005	0.0017
1977	25	20	0.0018				
1978	20	20	0.0039				
1979	20	20	0.0032				
1980	20	20	0.0042				
1981/82	27	27	0.0020				
1982/84	8	NA	0.0027				
			Toddlers (2 years old)				
1975	10	10	0.0064				
1976	10	10	0.0042	0.0158	Trace	0.0038	Trace
1977	12	12	0.0219	0.0134	0.0621	0.0068	0.0048
1978	10	10	0.0145				
1979	10	10	0.0077				
1980	10	10	0.0058				
1981/82	13	13	0.0046				
1982/84	8	NA	0.0044				
			Infants (6 months old)				
1975	10	10	0.0044				
1976	10	10	0.0009	0.0031	0.0000	0.0001	Trace
1977	12	12	0.0382	0.0095	0.1433	0.0002	Trace
1978	10	10	0.0116				
1979	10	10	0.0101				
1980	10	10	0.0061				
1981/82	13	13	0.0056				
1982/84	8	NA	0.0017				

NA - Not available.

[a]Typical body weights assumed by FDA are: 69.1 kg for adults; 13.7 kg for toddlers and 8.2 kg for infants.

[b]Geographic regional average intakes are available only for those years listed.



*The dramatic increase in intake for both toddlers and infants during 1977 was apparently caused by the detection of a relatively high concentration of HCB in one of the whole milk composites (3 ppb). Because of the high intake of milk by these age groups and the skewing effect of this one sample on the calculated average HCB level in milk, the calculated HCB intake may be unrealistically high.

Figure 5-2. FDA total diet studies-HCB daily dietary intake, 1970-1984.

Table 5-2. FDA Total Diet Studies for Infants - Summary of HCB Detection Frequency in Market Basket Samples for Fiscal Years 1975 - 1980

Food class	Percent of market basket samples that contain HCB residues[a]						
	1975	1976	1977	1978	1979	1980	1981/82
Drinking water	ND	ND	ND	ND	ND	ND	ND
Whole milk	20	ND	33	50	50	30	15
Other dairy products	10	ND	25	40	40	30	ND
Meat, fish, and poultry	30	20	17	40	30	30	23
Grain and cereal products	ND	ND	ND	ND	ND	ND	ND
Potatoes	ND	13	ND	13	ND	ND	ND
Vegetables	ND	ND	8.3	ND	ND	ND	ND
Fruit and fruit juices	ND	ND	ND	ND	ND	ND	ND
Oils and fats	33	ND	100	100	30	20	23
Sugar and adjuncts	ND	ND	ND	ND	ND	ND	ND
Beverages	ND	ND	ND	ND	ND	ND	ND
Total	7.0	3.1	11.1	17	14	10	5.6

ND - Not dectected.

[a] Includes samples containing "trace" residues of HCB (i.e., detected, but too low to quantify). Although the nominal limit of quantification of the analytical method for organochlorine pesticides is 0.002 ppm and the nominal limit of detection is 0.001 ppm, lower levels of HCB have been quantified or detected in some samples.

Table 5-3. FDA Total Diet Studies for Toddlers - Summary of HCB Detection Frequency in Market Basket Samples for Fiscal Years 1975 - 1980

Food class	Percent of market basket samples that contain HCB residues[a]						
	1975	1976	1977	1978	1979	1980	1981/82
Drinking water	ND	ND	ND	ND	ND	ND	ND
Whole milk	20	ND	33	50	50	30	15
Other dairy products	30	50	67	80	80	90	62
Meat, fish, and poultry	30	40	50	60	70	70	46
Grain and cereal products	ND	ND	ND	ND	ND	ND	ND
Potatoes	ND	10	8.3	10	ND	ND	ND
Vegetables	ND	ND	ND	ND	ND	ND	ND
Fruit and fruit juices	ND	ND	ND	ND	ND	ND	ND
Oils and fats	40	40	58	90	100	100	9.2
Sugar and adjuncts	ND	ND	8.3	ND	ND	ND	7.7
Beverages	ND	ND	ND	ND	ND	ND	ND
Total	11	13	20	26	30	26	20

ND - Not dectected.

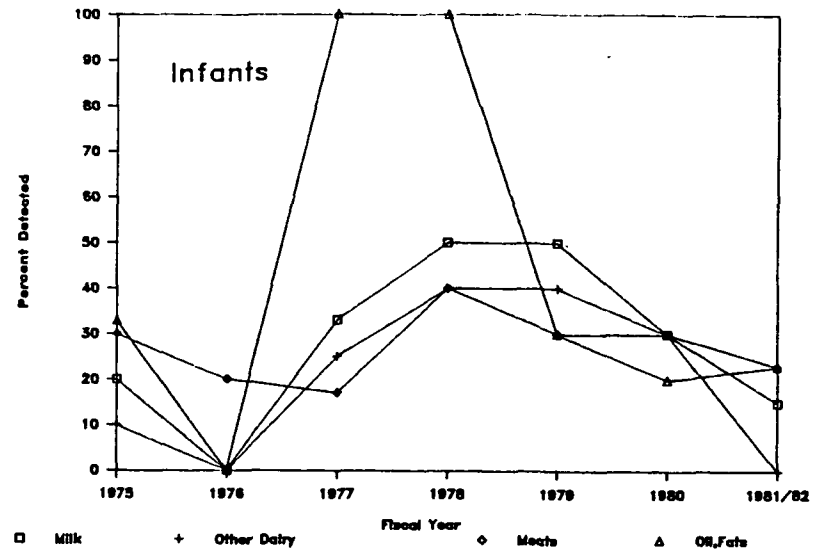
[a] Includes samples containing "trace" residues of HCB (i.e., detected but too low to quantify). Although the nominal limit of quantification of the analytical method for organochlorine pesticides is 0.002 ppm and the nominal limit of detection is 0.001 ppm, lower levels of HCB have been quantified or detected in some samples.

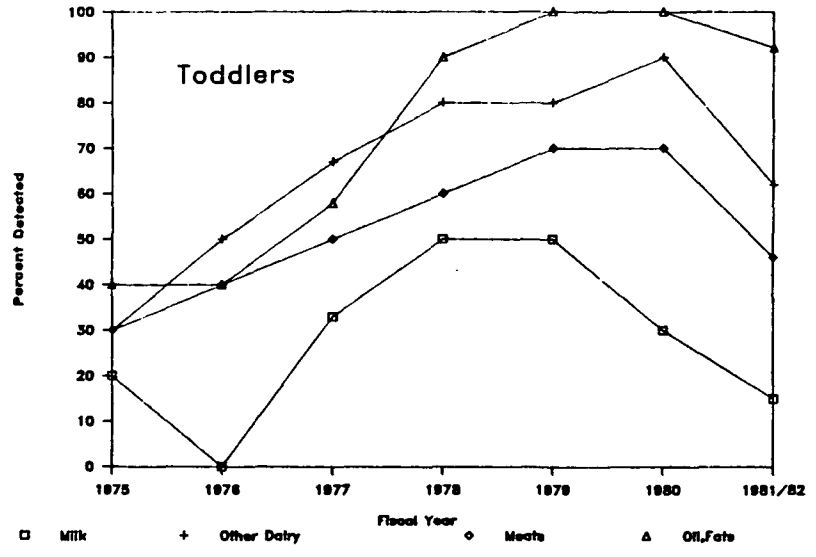
Table 5-4. FDA Total Diet Studies for Adults - Summary of HCB Detection Frequency in Market Basket Samples for Fiscal Years, 1970-1982

Food class	Percent positive market baskets (≥0.001 ppm HCB)[a]											
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981/82
Dairy products	ND	13	ND	3.3	10	40	25	20	50	70	40	15
Meat, fish, and poultry	6.7	3.3	ND	6.7	13	35	55	68	90	100	75	59
Grain and cereal products	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potatoes	ND	ND	ND	ND	3.3	ND	ND	ND	ND	5.0	ND	ND
Leafy vegetables	ND	3.3	2.8	ND	ND	ND	ND	ND	5.0	ND	ND	ND
Legume vegetables	ND	ND	ND	ND	3.3	ND	ND	ND	ND	ND	ND	ND
Root vegetables	ND	ND	ND	3.3	3.3	ND	ND	ND	ND	ND	ND	ND
Garden fruit	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fruits	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Oils, fats, and shortening	13	ND	8.6	20	23	20	15	40	95	65	70	82
Sugar and adjuncts	ND	ND	ND	ND	ND	5.0	ND	4.0	5.0	ND	20	15
Beverages	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total	1.7	1.7	1.0	2.8	4.7	8.3	7.9	11	20	20	17	14

ND - Not detected.

[a]Includes samples containing "trace" residues of HCB (i.e., detected, but too low to quantify). Although the nominal limit of quantification of the analytical method for organochlorine pesticides is 0.002 ppm and the nominal limit of detection is 0.001 ppm, lower levels of HCB have been quantified or detected in some samples.





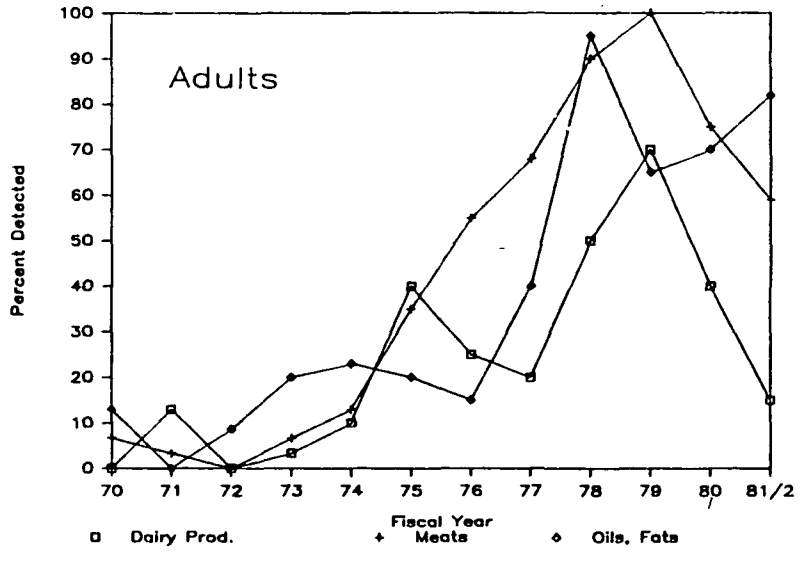
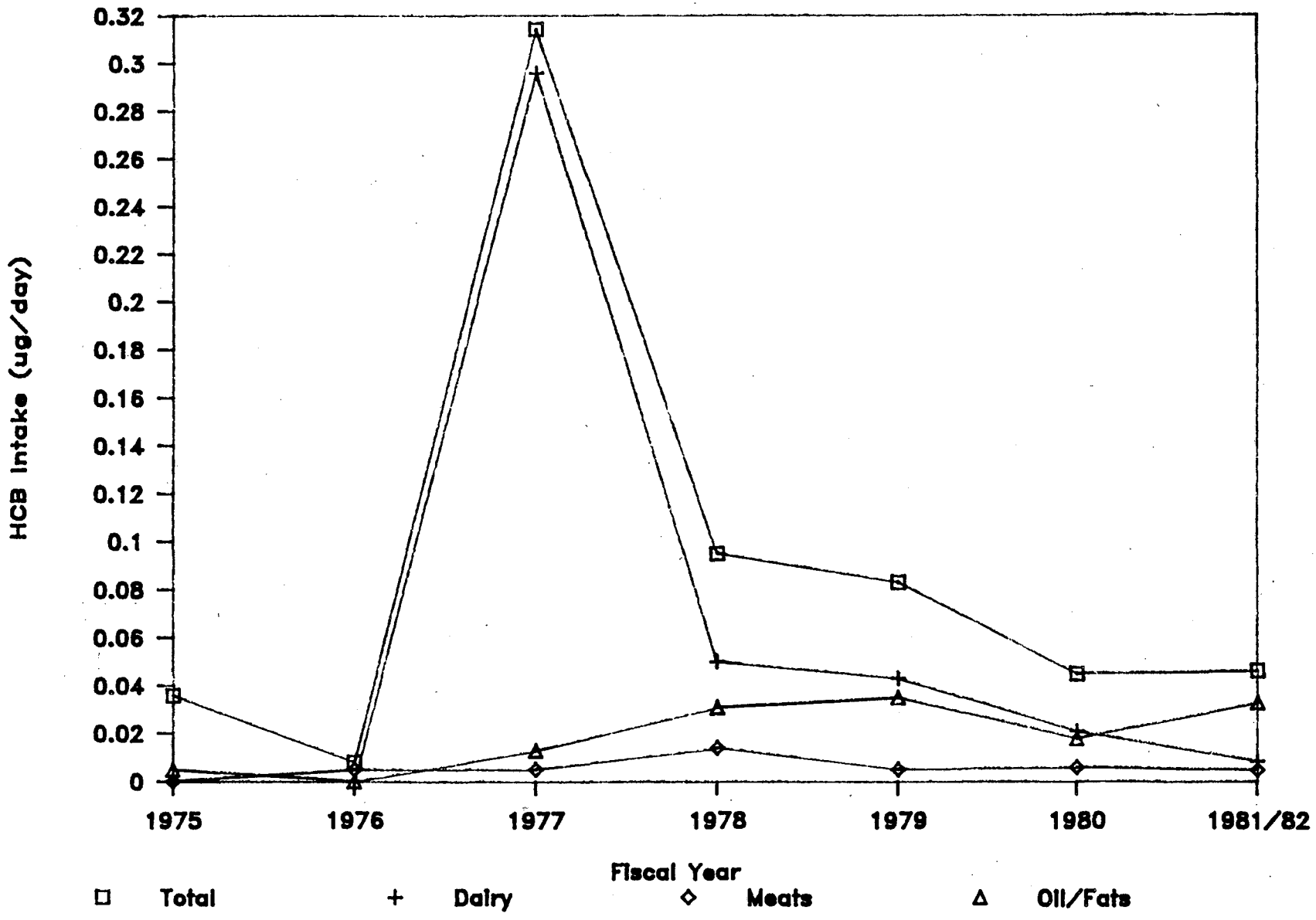
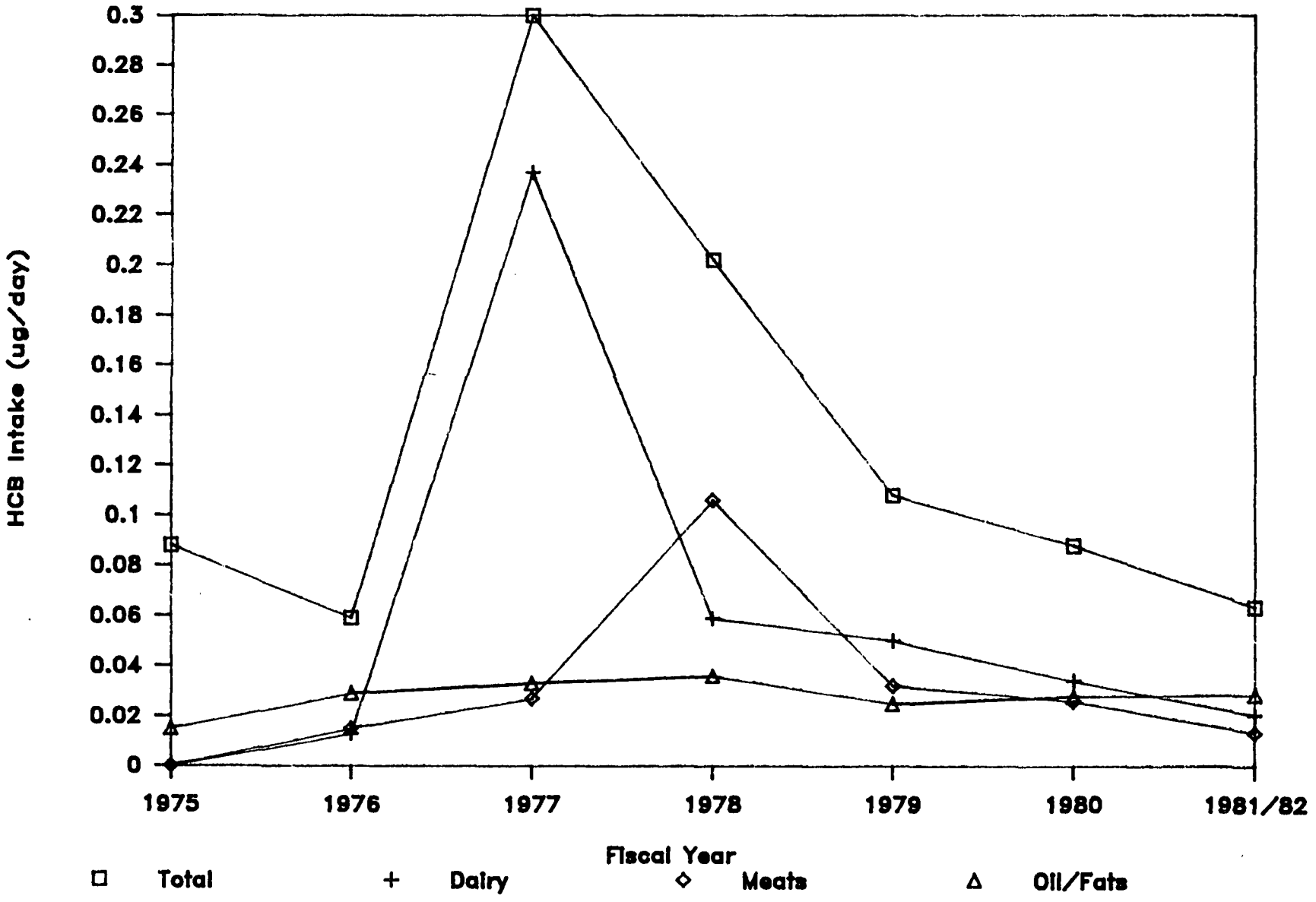


Figure 5-3. FDA total diet studies for infants, toddlers, and adults, HCB detection frequency, 1975-1982.



*The dramatic increase in intake for both toddlers and infants during 1977 was apparently caused by the detection of a relatively high concentration of HCB in one of the whole milk composites (3 ppb). Because of the high intake of milk by these age groups and the skewing effect of this one sample on the calculated average HCB level in milk, the calculated HCB intake may be unrealistically high.

Figure 5-4. FDA total diet studie infants, HCB intake (ug/day), 1975-1982.



*The dramatic increase in intake for both toddlers and infants during 1977 was apparently caused by the detection of a relatively high concentration of HCB in one of the whole milk composites (3 ppb). Because of the high intake of milk by these age groups and the skewing effect of this one sample on the calculated average HCB level in milk, the calculated HCB intake may be unrealistically high.

Figure 5-5. FDA total diet studies for toddlers, HCB intake (ug/day), 1975-1982.

During the 1973 through 1978 surveys , individual food items in the adult dairy products and meat-fish-poultry food classes were analyzed for HCB. Tables 5-5 and 5-6 summarize the results of the analyses for these two food classes, respectively. Even when detected, HCB residues were low; however, there is a distinct peak in the percent occurrence of HCB in 1976 to 1978.

5.2 FDA Surveillance Monitoring Data

5.2.1 Program Description

FDA's monitoring program for domestic and imported foods involves the testing of large numbers of samples of fresh fruits, fresh vegetables, grains, animal feedstuffs, milk and dairy products, fish, and a variety of processed products and by-products. FDA conducts both surveillance and compliance monitoring. Surveillance samples are those samples collected without suspicion of excessive residues or pesticide chemical misuse. Compliance samples are those collected when excessive residues are suspected. Only the results of the surveillance monitoring are included in this report.

Domestic samples are usually collected at major harvesting and distribution points throughout the United States. Samples of imported food are collected at ports of entry into the United States. All samples are analyzed in FDA laboratories primarily by multiresidue methods of analysis. Limits of quantitation for HCB are generally about 0.01 ppm. Commodity priorities for testing may be modified annually and may be different for domestic and imported foods (Duggan et al. 1983).

5.2.2 Summary of Results

(1) Foods. With the exception of fiscal year (FY) 1977, the results of domestic surveillance sampling are available for fiscal years 1970 through 1984. The results of import surveillance sampling are available for FY 1978 through 1984; before 1978, samples of imported food were not identified separately for surveillance and compliance purposes. The sampling results summarized in this section were obtained from two sources. Results for FY 1970 through 1976 were obtained from an FDA report (Duggan et al. 1983) that presents summary data for commodity groups (i.e., root vegetables, fruits, etc.). Results for FY 1978 through 1984 were supplied in computer printouts to EPA by the FDA Center for Food Safety and Applied Nutrition. These printouts contain commodity-specific results (e.g., peanuts, apples, etc.) enabling more accurate identification of the actual foods in which HCB has been detected.

Table 5-5. FDA Total Diet Studies - HCB Residues in Individual Commodities of the Adult Dairy Composite for Fiscal Years 1973 to 1978

Commodity	Frequency of detection						Range of detected values (ppb)[a]					
	1973	1974	1975	1976	1977	1978	1973	1974	1975	1976	1977	1978
Whole milk	1/4	0/4	0/4	1/4	2/4	1/4	T	----	----	T	T	T
Evaporated milk	1/4	0/4	1/4	2/4	3/4	1/4	T	----	T	T	T	T
Buttermilk	0/?	0/?	0/?	0/?	0/1	0/1	----	----	----	----	----	----
Nonfat dry milk	0/?	0/?	0/?	0/?	0/4	0/4	----	----	----	----	----	----
Ice cream	0/4	0/4	1/4	3/4	3/4	3/4	----	----	T	T	T-1	1-3
Cottage cheese	0/4	0/4	0/4	1/4	1/4	1/4	----	----	----	1	T	T
Processed cheese	0/4	0/4	2/4	3/4	4/4	4/4	----	----	T-2	T-1	T-3	T-1
Natural cheese	0/4	0/4	0/4	3/4	4/4	4/4	----	----	----	T-2	T-1	T-2
Butter	0/4	0/4	3/4	4/4	4/4	4/4	----	----	2-6	T-4	T-4	2-4
Skim milk	0/?	0/?	0/?	1/4	?/3	0/4	----	----	----	T	T	----
Ice milk	0/3	0/3	0/2	1/2	1/2	2/4	----	----	----	T	T	T-1
Total	2/~43	0/~43	7/42	19/43	23/38	20/41	T	----	T-6	T-4	T-3	T-4
Percent detected	(4.6%)	(0%)	(17%)	(44%)	(61%)	(49%)						

[a]T = trace, which is less than 1 ppb.

Source: Johnson and Manske (1976, 1977), Manske and Johnson (1977), Johnson et al. (1981, 1984), Podrebarac (1984).

Table 5-6. FDA Total Diet Studies - HCB Residues in Individual Commodities of the Adult Meat-Fish-Poultry Composite for Fiscal Years 1973 to 1978

Commodity	Frequency of detection						Range of detected values (ppb)[a]					
	1973	1974	1975	1976	1977	1978	1973	1974	1975	1976	1977	1978
Roast beef	2/4	0/4	0/4	3/4	4/4	3/4	2-7	----	----	T-2	T-5	T
Ground beef	0/4	0/4	2/4	2/4	4/4	4/4	----	----	T	2	T-3	T-1
Pork chops	0/4	0/4	0/4	1/4	0/4	1/4	----	----	----	2	----	T
Bacon	0/4	0/4	0/4	1/4	2/4	0/4	----	----	----	30	T	----
Chicken	0/4	0/4	0/4	2/4	0/4	2/4	----	----	----	2-8	----	T
Fish fillet	1/4	1/4	1/4	2/4	3/4	2/4	2	1	1	T-3	T-5	T-4
Canned fish	0/4	0/4	2/4	1/4	1/4	1/4	----	----	T-2	T	3	1
Shrimp	0/?	0/?	0/2	0/2	0/2	0/2	----	----	----	----	----	----
Lunch meat	0/4	0/4	2/4	2/4	3/4	3/4	----	----	T-3	T-2	T-1	T
Frankfurters	0/4	0/4	0/4	2/4	4/4	4/4	----	----	----	1-2	T-2	T
Beef liver	1/4	0/4	0/4	1/4	2/4	2/4	2	----	----	T	T-1	T-1
Eggs	0/4	0/4	0/4	2/4	2/4	1/4	----	----	----	T	T-1	T
Ham	0/4	0/4	0/4	0/4	1/4	0/4	----	----	----	----	T	----
Round steak	1/4	0/4	1/1	0/1	2/4	1/4	1	----	T	T	T	T
Veal	0/2	0/4	1/1	0/1	2/2	2/2	----	----	2	----	1	T-1
Lamb	1/3	1/1	0/?	2/2	1/2	2/2	1	16	----	2	3	T-2
Total	6/~59	2/~59	9/~57	23/57	31/58	28/58	1-7	1-16	T-3	T-30	T-5	T-4
Percent detected	(10%)	(3.4%)	(16%)	(40%)	(53%)	(48%)						

[a]T = trace, which is less than 1 ppb.

Source: Johnson and Manske (1976, 1977), Manske and Johnson (1977), Johnson et al. (1981, 1984), Podrebarac (1984).

During the period 1970 to 1984, more than 71,000 samples of domestic food were analyzed for HCB residues. HCB was detected (including trace levels of less than 0.01 ppm) in slightly less than two percent of the samples tested. During the period FY 1978 to 1984, HCB was detected in 2.3 percent of the tested domestic foods when trace values are included, but in only 0.60 percent of the foods when trace values are excluded; differentiation between trace and non-trace detections is not possible for the FY 1970 to 1976 results. HCB was detected in 1.34 percent of the more than 19,000 samples of imported food tested during FY 1978 to 1984 (0.41 percent if trace values are excluded).

Although the overall HCB detection frequency has been low (less than 2 percent of all samples) in both foreign and domestic foods, HCB has been detected much more frequently in certain commodity groups and individual product types than in others. For example, although dairy products and fish, taken as a group, account for 21.2 percent of all domestic samples analyzed and 7.5 percent of all imported samples analyzed, they account for 86.4 percent of all HCB detections in domestic foods and 66.5 percent of the detections in imported foods. Table 5-7 summarizes the HCB detection frequencies in 39 commodity groups over the period FY 1970 to 1984. As can be seen from the table, HCB has been detected in samples from 19 of the 39 commodity groups. Appendix A provides tables showing more detailed summaries of these data for each year of sampling.

Table 5-8 lists individual products (except for individual types of cheese and fish) in which HCB has been detected at quantifiable levels (i.e., $\geq$0.01 ppm) during FY 1978 through 1984. In addition to dairy products and fish, HCB was detected in more than 0.5 percent of the domestic samples of the following products: wheat, peanuts, stringbeans, squash, lettuce, parsley, carrots, parsnips, and potatoes. Table 5-9 lists those individual products in which HCB has been detected at only trace levels during FY 1978 through 1984.

No attempt has been made to quantitatively measure residue trends, primarily because there is no assurance that similar or equivalent products are represented for comparison of samples on an annual basis. Table 5-10, however, shows that for four major commodity groupings (fish, milk/cheese, fruits, and vegetables) there has been no readily discernible temporal trend in the overall detection frequency.

(2) Animal feeds. HCB was detected in only 1 percent of the more than 5,000 animal feed samples analyzed by FDA during the period FY 1970 to 1976. Table 5-11 summarizes the results of this FDA testing for HCB. Overall, the HCB detection frequency was low and when detected the levels

Table 5-7. Summary of FDA Domestic and Import Surveillance Monitoring for 1970 to 1984[a]

Product code	Commodity group	Number of samples			% Positive (including trace values)[b]			% Positive (not including trace values)	
		1970-1976 Domestic	1978-1984 Domestic	1978-1984 Import	1970-1976 Domestic	1978-1984 Domestic	1978-1984 Import	1978-1984 Domestic	1978-1984 Import
02A	Whole grains	1032	1952	42	0.10	0.56	4.76	0.26	0
02B-Y	Milled grain products		136	76		0	0	0	0
03	Bakery products		14	6		0	0	0	0
04	Macaroni and noodle products		0	78		-	11.54	-	1.28
05	Cereal preparations		6	8		0	0	0	0
07	Snack food items		12	3		0	0	0	0
09A	Butter		145	8		13.79	25.00	2.07	0
09C-I	Milk and milk products	4441	3165	51	3.25	3.00	3.92	0.57	0
12	Cheese and cheese products	758	764	443	2.11	4.97	19.64	0.39	6.55
13	Ice cream and related products		71	2		0	0	0	0
14	Imitation milk products		19	0		0	-	0	-
15	Egg and egg products	2445	2607	264	0.61	0.31	0.38	0.08	0.38
16A-D	Fish and fish products	2898	3157	951	5.52	18.40	8.62	5.23	1.47
16E-G	Shellfish	443	364	65	1.13	1.10	3.08	0	0
16J-L	Crustaceans		358	90		0.84	3.33	0	0
16M-Y	Other aquatic animals and products		38	37		0	8.11	0	5.40
18	Vegetable protein products		1	0		0	-	0	-
20-22	Fruits and fruit products	4603	7820	3729	0.37	0.43	0.05	0	0.03
23	Nuts and edible seeds	174	906	264	2.30	4.64	1.52	2.54	0.38
24A-L	Beans, vine, and ear vegetables	3396	6809	10,753	0.05	0.73	0.18	0.12	0.06
24T-V	Leaf and stem vegetables	5134	7388	1172	1.36	0.26	0	0.07	0
25A-C	Mushrooms		182	102		1.65	3.92	1.10	1.96
25J-N	Root and tuber vegetables	3178	4094	789	1.07	0.71	3.80	0.20	2.53
26	Vegetable oils		155	23		0	0	0	0
27	Dressings and condiments		3	3		0	0	0	0

Table 5-7. (Continued)

Product code	Commodity group	Number of samples 1970–1976 Domestic	Number of samples 1978–1984 Domestic	Number of samples 1978–1984 Import	% Positive (including trace values)[b] 1970–1976 Domestic	% Positive (including trace values)[b] 1978–1984 Domestic	% Positive (including trace values)[b] 1978–1984 Import	% Positive (not including trace values) 1978–1984 Domestic	% Positive (not including trace values) 1978–1984 Import
28	Spices, flavors, and salts		117	284		0	2.82	0	0.35
29	Soft drinks and waters		24	5		0	0	0	0
30	Beverage bases, concentrates, and nectars		2	8		0	0	0	0
[illegible]	Coffee and tea		12	78		0	0	0	0
[illegible]	Alcoholic beverages		30	7		0	0	0	0
[illegible]	Candy without chocolate		0	6		-	0	-	0
34	Chocolate and cocoa products		0	13		-	7.69	-	0
35	Gelatin, rennet, pudding, and pie mixes		0	3		-	0	-	0
36	Food sweeteners		51	19		0	0	0	0
37	Multiple food dinners, gravies, and sauces		21	8		0	0	0	0
38	Soups		3	9		0	0	0	0
40	Infant and junior food products	471	18	0	0.64	0	-	0	-
41	Dietary conventional foods		2	0		0	-	0	-
45–46	Food additives		0	5		-	0	-	0

[a]Data for 1970–76 obtained from Duggan et al. (1983); results were not reported for all commodity groups. Data for 1978–84 obtained from FDA Center for Food Safety and Applied Nutrition. Detection limit is 0.01 ppm. Trace levels were not analytically confirmed.

Table 5-8. Summary of FDA Surveillance Data (1978-1984) for Food Products Containing Quantifiable Levels of HCB[a]

Product	Number of samples	% Positive (including[b] trace values)	% Positive (not including trace values)	Range of positive values (ppm)	Years in which detected
Domestic products					
Wheat	809	0.99	0.62	T-5.28	79, 81, 82
Butter	145	13.79	2.10	T-0.01	82-84
Milk	3165	3.00	0.57	T-0.27	78-84
Cheese	764	4.97	0.39	T-0.02	78, 80-83
Eggs (chicken)	2607	0.31	0.08	T-0.01	79, 80, 82-84
Fish	3157	18.40	5.23	T-0.42	78-84
Peanuts (in shell)	195	1.54	0.51	T-0.06	78, 79
Peanuts (shelled)	217	15.21	8.29	T-0.13	78-80, 84
Peanut butter	10	60.00	40.00	T-0.014	83, 84
Stringbeans	656	1.52	0.15	T-0.01	78-81
Squash	641	1.56	1.09	T-0.06	79-83
Lettuce	2649	0.60	0.15	T-0.03	78, 79, 81, 83
Parsley	130	0.77	0.77	0.01	78
Mushrooms	182	0.16	0.11	T-0.07	79, 80
Carrots	762	1.57	0.66	T-0.06	78-83
Parsnips	33	6.06	3.03	T-0.01	78, 80
Potatoes	1651	0.73	0.12	T-0.01	79, 80, 84
Imported products					
Macaroni	33	9.09	3.03	T-0.01	78, 80
Cheese	443	19.64	6.55	T-200	78-83
Eggs (duck)	192	0.52	0.52	0.08	79
Fish	951	8.62	1.47	T-700	78-84
Cod liver oil	13	15.38	15.38	0.10-0.14	80
Pears	36	2.78	2.78	0.01	84
Pumpkin seeds	5	20.00	20.00	0.03	83
Navy beans	5	20.00	20.00	0.02	80
"Other" beans	233	2.14	0.43	T-0.01	79-82

Table 5-8. (Continued)

Product	Number of samples	% Positive (including[b] trace values)	% Positive (not including trace values)	Range of positive values (ppm)	Years in which detected
Imported products					
Squash	1395	0.79	0.36	T-0.02	80-84
Mushrooms	102	3.92	1.96	T-0.40	78-80
Carrots	165	17.58	11.52	T-0.05	78-84
Parsnips	8	12.50	12.50	0.13	84
Caraway seeds	8	50.00	12.50	T-0.02	79, 81, 83

[a]Data supplied by FDA Center for Food Safety and Applied Nutrition.
[b]Detection limit of 0.01 ppm. Trace levels were not analytically confirmed.

Table 5-9. Summary of FDA Surveillance Data (1978-1984) for Food Products Containing Only Trace Levels of HCB[a,b]

Product	Number of samples	% Positive	Number positive
Domestic products			
Corn	152	0.66	1
Oysters	145	2.76	4
Lobsters	91	2.20	2
Shrimp	58	1.72	1
Grapes	391	1.02	4
Apples	1550	0.71	11
Pears	424	0.24	1
Peaches	914	0.33	3
Cantalopes	290	0.69	2
Plums	?	?	1
Broccoli	459	0.22	1
Red beets	128	2.34	3
Soybeans	59	1.69	1
Sweet peas	547	0.55	3
Eggplant	157	0.64	1
Peppers	625	0.32	2
Cucumbers	682	0.73	5
Imported products			
Rice	28	7.14	2
Spaghetti	19	21.05	4
Vermicelli	1	100	1
Butter	8	25.00	2
Milk	51	3.92	2
Oysters	20	10.00	2
Lobsters	13	23.08	3
Squid	2	50.00	1
Peaches	61	1.64	1
Sesame seeds	63	3.17	2
Brazil nuts	6	16.67	1
Chick-peas	21	4.76	1
Peppers	2235	0.04	1
Water chestnuts	?	?	1
Fennel	1	100	1
Coriander	127	0.79	1
"Other" spices	10	20.00	2
Chocolate liquor	2	50.00	1

[a]Data supplied by FDR Center for Food Safety and Applied Nutrition.
[b]Detection limit is 0.01 ppm. Trace levels were not analytically confirmed.

Table 5-10 Summary of FDA Domestic Surveillance Data for HCB for Four Major Commodity Groupings

Fiscal year	HCB detection frequency (%) (including trace values)[a,b]			
	Fish	Milk/cheese	Fruits	Vegetables
1970	1.3	0.4	0	1.1
1971	0.3	2.3	0.2	1.5
1972	0.8	2.9	0	1.2
1973	5.9	5.8	0.9	1.0
1974	12.0	3.8	1.6	0.5
1975	3.3	5.0	0	0.6
1976	8.4	1.2	0.1	0.9
1978	11.0	4.9	0.8	0.6
1979	13.5	2.8	0.2	0.8
1980	26.9	0.9	0.8	0.7
1981	19.3	5.5	0.4	1.0
1982	35.7	5.9	0.8	0.3
1983	18.4	2.4	0	0.4
1984	6.6	1.0	0	0.1

[a]Nominal limit of quantification is 0.01 ppm.
[b]Available data for 1970 to 1976 do not allow differentiation between trace and non-trace values.

Table 5-11. FDA Domestic Surveillance Summary Data for Animal Feeds

Animal feed commodity	1970	1971	1972	1973	1974	1975	1976	1970-1976
				Number of samples				
Whole grain	89	82	226	265	145	68	31	906
Hay	138	82	24	17	-	50	37	348
Dehydrated hay	26	37	8	7	-	20	36	134
Animal byproducts	18	15	5	78	98	154	236	604
Fish byproducts	12	9	86	30	25	41	83	286
Misc. animal feed	139	119	537	118	37	109	98	1157
Cereal byproducts	?	?	?	?	?	?	?	166
				Percent positive samples[a]				
Whole grain	0	0	0	1.13	0	0	22.58	1.10
Hay	0	1.22	0	0	-	8.00	16.22	3.16
Dehydrated hay	0	0	0	0	-	0	8.33	2.24
Animal byproducts	0	0	0	5.13	1.02	0.65	0.42	1.16
Fish byproducts	41.77	0	1.16	0	0	0	8.43	4.55
Misc. animal feed	0	0	0.37	2.54	0	2.75	2.04	0.60
Cereal byproducts	?	?	?	?	?	?	?	0.60
				Average concentration (ppb)				
Whole grain	0	0	0	1	0	0	14	0.
Hay	0	0.9	0	0	-	1	2	0.6
Dehydrated hay	0	0	0	0	-	0	1	0.3
Animal byproducts	0	0	0	0.8	0.7	0.1	0.1	0.2
Fish byproducts	20	0	0.2	0	0	0	2	2
Misc. animal feed	0	0	<0.1	0.4	0	3	0.9	0.4
Cereal byproducts	?	?	?	?	?	?	?	?

Commodities in which HCB was apparently not detected[a] (1970-1976)

Animal feeds	Number of samples
Oilseed byproducts	551
Ground grains	453
Vegetable byproducts	250
Silage	272

[a]Detection limit is 10 ppb.
Source: Duggan et al. (1983).

were also low. No readily discernible trend appears in the detection frequency except possibly in 1976, when relatively high detection frequencies were observed in several of the commodities. Duggan et al. (1983) caution against using these data to speculate on trends or relationships because of the relatively small number of samples and the variation in the number of samples tested from year to year.

Data for the fiscal years 1978 to 1984 were also supplied to EPA by the FDA Center for Food Safety and Applied Nutrition. Because the supplied data did not include total counts of numbers of individual commodities tested, it is not possible to calculate detection frequencies for these years. However, the supplied data provide an indication of the individual commodities in which HCB was detected. Table 5-12 summarizes these results. The results indicate that grain screenings, animal (mammal) byproducts, and fish byproducts account for the majority of the detections.

5.3 National Pesticide Monitoring Program Activities of the FWS

The National Pesticide Monitoring Program (NPMP) was established in the mid-1960s to assess temporal and geographic contaminant trends in selected environmental components. The U.S. Fish and Wildlife Service (FWS), U.S. Department of the Interior, contributes to this program by periodically determining contaminant levels in freshwater fish, starlings, and waterfowl. This section summarizes the results of the FWS residue analyses for HCB during the 1970s and early 1980s; analyses of HCB residues were not performed prior to the early 1970s.

5.3.1 FWS Monitoring Network for Freshwater Fish

(1) Network description. FWS began nationwide monitoring of HCB residues in freshwater fish as part of the NPMP in 1971. Fish are collected from a network of 117 sampling sites in major river basins throughout the United States and in the Great Lakes (see Figure 5-6 and Table 5-13). Prior to 1976, collections were made annually. Since 1976, collections have been made biannually. Three samples are typically collected at each site -- two of a representative bottom-feeding species and one of a representative predator species. Each sample consists of three to five whole adult fish, composited and thoroughly homogenized for chemical analysis.

(2) Summary of results. HCB residue levels have been determined for fish collections in the years 1971-1974, 1976-1979, and 1980-1981 (Schmitt et al. 1981, Schmitt et al. 1983, and Schmitt et al. 1985, respectively). HCB analyses from 1971 to 1974 were conducted only as

Table 5-12. Summary of FDA Domestic Surveillance Data (1978-1984) for Animal Feeds Containing Detectable Levels of HCB

Animal feed	Number of positive samples[a]	Range of positive values (ppm)
Whole or ground grains		
- Barley	1	0.07
- Corn	1	T[b]
- Oats	1	T
- Mixed	1	T
Grain screenings		
- Barley	21	T-0.08
- Corn	2	T-0.01
- Wheat	20	T-1.25
Grass hay	1	T
Other hay	1	T
Mixed feed for cattle	1	T
Mixed feed for poultry	2	T
Animal (mammal) byproducts	31	T-0.08
Animal (poultry) byproducts	1	T
Fish byproducts	32	T-0.24
Spent brewery malt barley	1	0.01
Carrot byproducts	1	T
Oilseed byproducts	11	T-0.05

[a]Includes trace values (i.e. < 0.01 ppm).
[b]T = trace.

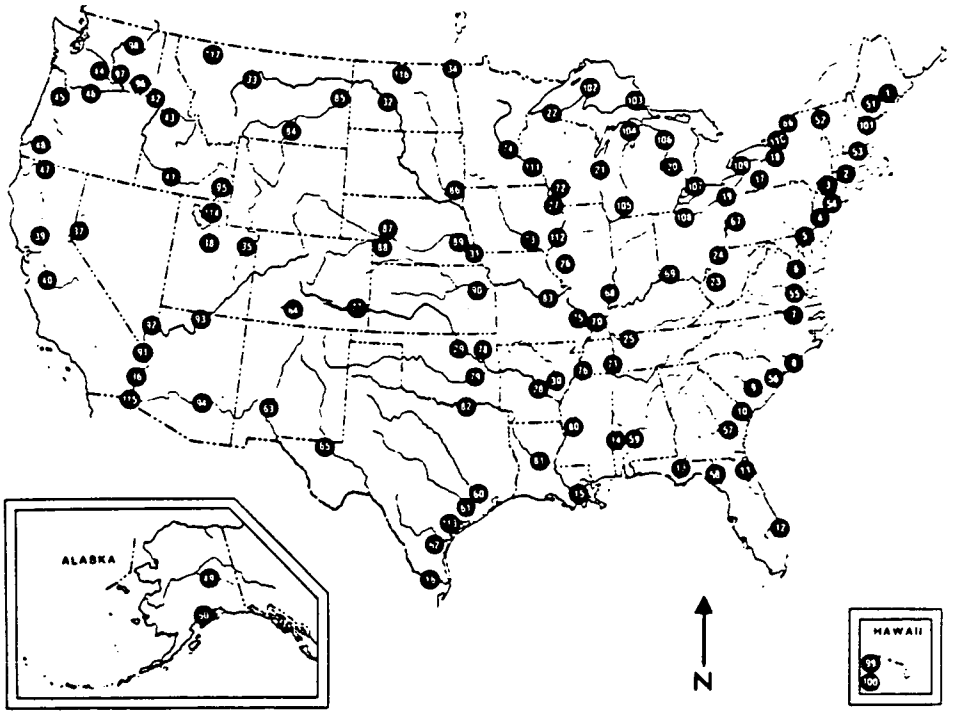


Figure 5-6. FWS national pesticide monitoring program - fish collection stations.[a]

[a]See Table 5-13 for collection station locations.

Table 5-13. FWS National Pesticide Monitoring Program
Fish Collection Stations

Station	River or lake	Location
1	Penobscot River	Old Town, ME
2	Connecticut River	Windsor Locks, CT
3	Hudson River	Poughkeepsie, NY
4	Delaware River	Camden, NJ
5	Susquehanna River	Conowingo Dam, MD
6	Potomac River	Little Falls, MD
7	Roanoke River	Roanoke Rapids, NC
8	Cape Fear River	Elizabethtown, NC
9	Cooper River	Lake Moultrie, SC
10	Savannah River	Savannah, GA
11	St. Johns River	Welaka, FL
12	St. Lucie Canal	Indiantown, FL
13	Apalachicola River	J. Woodruff Dam, FL
14	Tombigbee River	McIntosh, AL
15	Mississippi River	Luling, LA
16	Rio Grande	Mission, TX
17	Genessee River	Scottsville, NY
18	Lake Ontario	Port Ontario, NY
19	Lake Erie	Erie, PA
20	Lake Huron (Saginaw Bay)	Bay Port, MI
21	Lake Michigan	Sheboygan, WI
23	Kanawha River	Winfield, WV
22	Lake Superior	Bayfield, WI
24	Ohio River	Marietta, OH
25	Cumberland River	Clarksville, TN
26	Illinois River	Beardstown, IL
27	Mississippi River	Guttenburg, IA
28	Arkansas River	Pine Bluff, AR
29	Arkansas River	Keystone Reservoir, OK
30	White River	Devalls Bluff, AR
31	Missouri River	Nebraska City, NE
32	Missouri River	Garrison Dam, ND
33	Missouri River	Great Falls, MT
34	Red River of the North	Noyes, MN
35	Green River	Vernal, UT

Table 5-13. (Continued)

Station	River or lake	Location
36	Colorado River	Imperial Reservoir, AZ
37	Truckee River	Fernley, NV
38	Utah Lake	Provo, UT
39	Sacramento River	Sacramento, CA
40	San Joaquin River	Los Banos, CA
41	Snake River	Hagerman, ID
42	Snake River	Lewiston, ID
43	Salmon River	Riggins, ID
44	Yakima River	Granger, WA
45	Willamette River	Oregon City, OR
46	Columbia River	Cascade Locks, OR
47	Klamath River	Hornbrook, CA
48	Rogue River	Goldray Dam, OR
49	Chena River	Fairbanks, AK
50	Kenai River	Soldatna, AK
51	Kennebec River	Hinckley, ME
52	Lake Champlain	Burlington, VT
53	Merrimac River	Lowell, MA
54	Raritan River	Highland Park, NJ
55	James River	Richmond, VA
56	Pee Dee River	Johnsonville, SC
57	Altamaha River	Doctortown, GA
58	Suwanee River	Old Town, FL
59	Alabama River	Chrysler, AL
60	Brazos River	Richmond, TX
61	Colorado River	Wharton, TX
62	Nuees River	Mathis, TX
63	Rio Grande	Elephant Butte, NM
64	Rio Grande	Alamosa, CO
65	Pecos River	Red Bluff Lake, TX
66	St. Lawrence River	Massena, NY
67	Allegheny River	Natrona, PA
68	Wabash River	New Harmony, IN
69	Ohio River	Cincinnati, OH
70	Ohio River	Metropolis, IL
71	Tennessee River	Savannah, TN

Table 5-13. (Continued)

Station	River or lake	Location
72	Wisconsin River	Woodman, WI
73	Des Moines River	Keosauqua, IA
74	Mississippi River	Little Falls, MN
75	Mississippi River	Cape Girardeau, MO
76	Mississippi River	Memphis, TN
77	Arkansas River	John Martin Reservoir, CO
78	Verdigris River	Oologah, OK
79	Canadian River	Eufaula, OK
80	Yazoo River	Redwood, MS
81	Red River	Alexandria, LA
82	Red River	Lake Texoma, OK
83	Missouri River	Hermann, MO
84	Big Horn River	Hardin, MT
85	Yellowstone River	Sidney, MT
86	James River	Olivet, SD
87	North Platte River	Lake McConaughy, NE
88	South Platte River	Burle, NE
89	Platte River	Louisville, NE
90	Kansas River	Bonner Springs, KS
91	Colorado River	Lake Havasu, AZ
92	Colorado River	Lake Mead, NV
93	Colorado River	Lake Powell, AZ
94	Gila River	San Carlos Reservoir, AZ
95	Bear River	Preston, ID
96	Snake River	Ice Harbor Dam, WA
97	Columbia River	Pasco, WA
98	Columbia River	Grand Coulee, WA
99	Waikele Stream	Waipahu, HI
100	Manoa Stream	Honolulu, HI
101	Androscoggin River	Lewiston, ME
102	Lake Superior	Keeweenaw Point, MI
103	Lake Superior	Whitefish Point, MI
104	Lake Michigan	Beaver Island, MI
105	Lake Michigan	Saugatuck, MI
106	Lake Huron	Alpena, MI
107	Lake St. Clair	Mt. Clemens, MI

Table 5-13. (Continued)

Station	River or lake	Location
108	Lake Erie	Port Clinton, OH
109	Lake Ontario	Roosevelt Beach, NY
110	Lake Ontario	Cape Vincent, NY
111	Mississippi River	Lake City, MN
112	Mississippi River	Dubuque, LA
113	San Antonio River	McFaddin, TX
114	Bear River	Brigham City, UT
115	Colorado River	Yuma, AZ
116	Souris River	Upham, ND
117	Flathead River	Creston, MT

part of crosscheck analyses of samples either known to contain high residue levels of chlorinated pesticides or collected at stations with a history of high residue levels. HCB analyses were routinely performed on all samples starting in 1976.

Table 5-14 summarizes the results of the fish surveys conducted from 1971 to 1981. Figures 5-7 and 5-8 are maps showing the locations of sites where HCB was detected in each survey.

Because of the large differences in the number of stations sampled in the early versus the later surveys as well as the probable bias of the early surveys to collection of contaminated fish, it is not possible to assess temporal and geographic trends for the ten-year period covered by the surveys. However, an assessment of trends for the last five survey years can be made by examining the results for those stations with continuous data from 1976 to 1981. Of the 106 to 108 stations sampled during the latter three surveys, 97 stations were sampled in each of the three surveys.

Table 5-15 presents a comparison of the results from the 1976-1977, 1978-1979, and 1980-1981 surveys for these 97 stations. There was a significant decrease in the mean HCB residue levels and occurrence frequencies between 1976-1977 and 1978-1979; there was no significant difference between the 1978-1979 and 1980-1981 results. Figure 5-9 shows the locations of the sites where HCB has been detected in at least two of these last three surveys. Table 5-16 lists the locations of the sites. HCB has consistently been detected in fish collected from sections of the Mobile, Ohio, Columbia, Merrimac, and Mississippi Rivers as well as in the Great Lakes.

5.3.2 FWS Monitoring Network for Starlings

(1) Network description. FWS began nationwide monitoring of HCB residues in starlings (Sturnus vulgaris) as part of the NPMP in 1972. Starlings were selected for monitoring because they are a terrestrial species; they are found throughout most of the contiguous 48 states; they are regarded as expendable; and their omnivorous feeding habits should reflect pesticide intake from insects, fruits, crops, and other foods (Cain and Bunck 1983).

The starling collection sampling design was originally described by Martin (1969). Basically, the procedure is to trap or shoot 10 starlings in the fall at each of up to 139 sites throughout the United States. The sites were chosen by selecting randomly up to four latitude and longitude coordinates within each 5 degree block of latitude and longitude in the

Table 5-14. Summary of the 1971 to 1981 HCB Residue Data from the FWS Fish Sampling Network[a]

Collection period	Number of stations	Number of samples[b]	Percent with detected HCB		Wet-weight residues (ug/g)		Lipid-weight residues (ug/g)	
			Stations	Samples	Max.	Geom. mean[c]	Max.	Geom. mean[c]
1980-81	107	315	24.3	14.6	0.12	<0.01	1.17	0.03
1978-79	108	314	21.3	14.0	0.13	<0.01	1.69	0.03
1976-77	106	310	45.2	28.1	0.70	0.01	6.42	0.09
1974	44	47	45.4	46.8	0.06	0.01	1.00	0.12
1973	32	38	65.6	60.5	4.20[d]	0.11	127[d]	0.16
1972	29	33	51.7	51.5	0.42	0.03	3.13	0.31
1971	29	30	79.3	76.7	1.00	0.08	5.29	0.57

[a]Because of the large differences in the number of stations sampled in the early versus the later surveys as well as the probable bias of the early surveys to collection of contaminated fish, it is not possible to reliably assess temporal trends for the entire ten-year period covered by the surveys.

[b]Each sample consists of three to five whole adult specimens of a single fish species.

[c]Geometric means were computed by transforming all values to the $\log_{10}$ (residue + 1.0) scale, averaging the transformed values, and back transforming the means to the arithmetic scale ($10^x - 1$, where x is the transformed mean).

[d]The maximum concentration of 4.20 ug/g (wet weight) was found in a sample with a lipid concentration of 3.3 percent.

Figure 5-7. FWS national pesticide monitoring program: HCB residues in freshwater fish, 1971-1974.

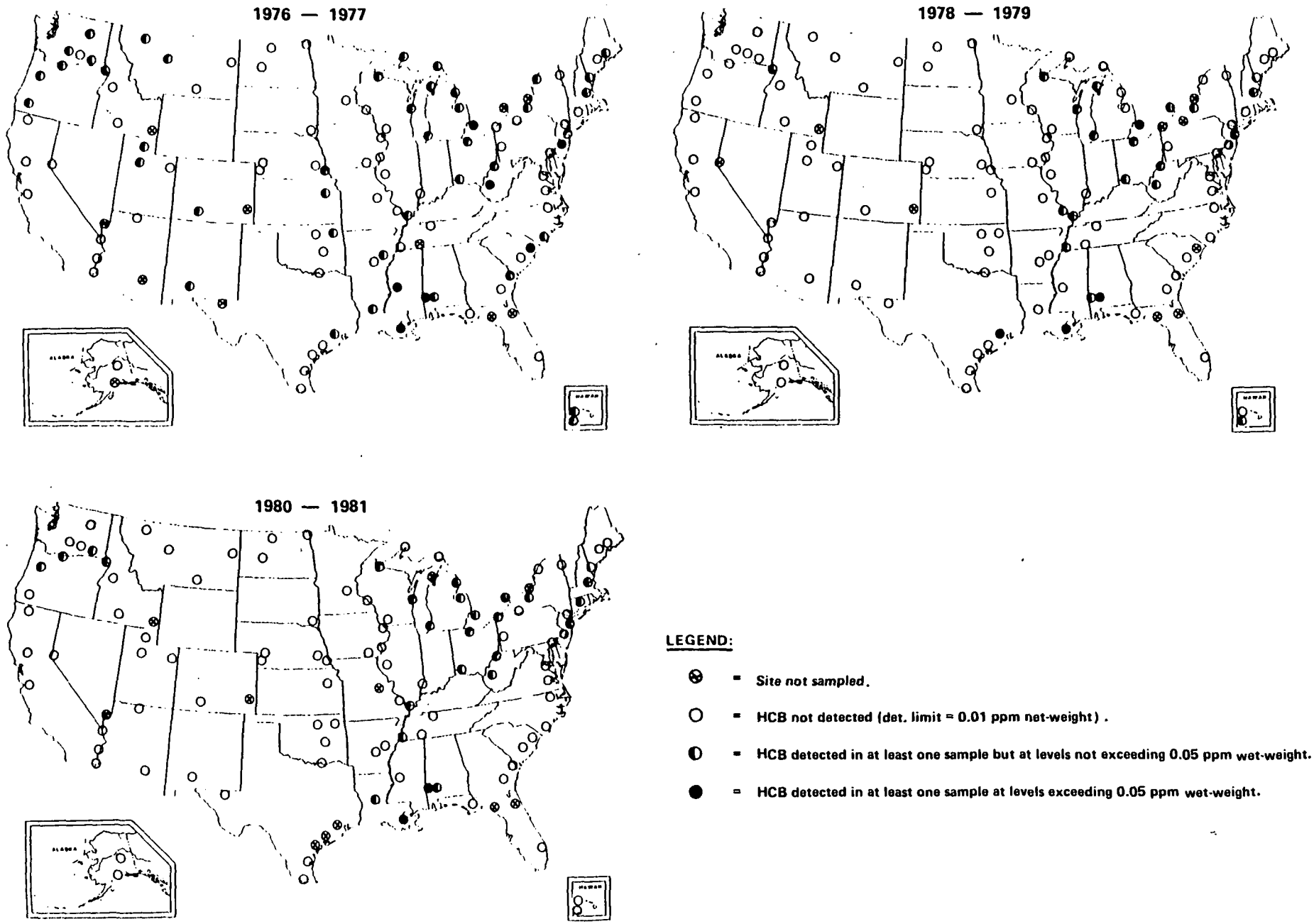


Figure 5-8. FWS national pesticide monitoring program: HCB residues in freshwater fish, 1976-1981.

Table 5-15. Summary of Results for the 97 FWS Fish Sampling Stations with Continuous Data for 1976 to 1981

	Sampling period		
	1976-1977	1978-1979	1980-1981
Percent of stations w/detected HCB (%)	46.4	20.6	24.7
Number of samples[a]	284	283	282
Percent of samples w/detected HCB (%)	28.9	13.1	15.6
Wet-weight mean[b] residue[c] (ug/g)	0.01	0.01	<0.01
Lipid-weight mean[b] residue[d] (ug/g)	0.09	0.03	0.03

[a]Each sample consists of 3 to 5 whole adult specimens of a single fish species.

[b]Geometric means were computed by transforming all values to the $\log_{10}$ (residue + 1.0) scale, averaging the transformed values, and back transforming the means to the arithmetic scale (10^x - 1, where x is the transformed mean).

[c]Although not significantly different from each other (ANOVA, $P \leq 0.05$), the 1978-1979 and 1980-1981 means are significantly different from the 1976-1977 mean (Schmitt et al. 1985).

[d]Although not significantly different from each other (ANOVA, $P \leq 0.01$), the 1978-1979 and 1980-1981 means are significantly different from the 1976-1977 mean (Schmitt et al. 1985).

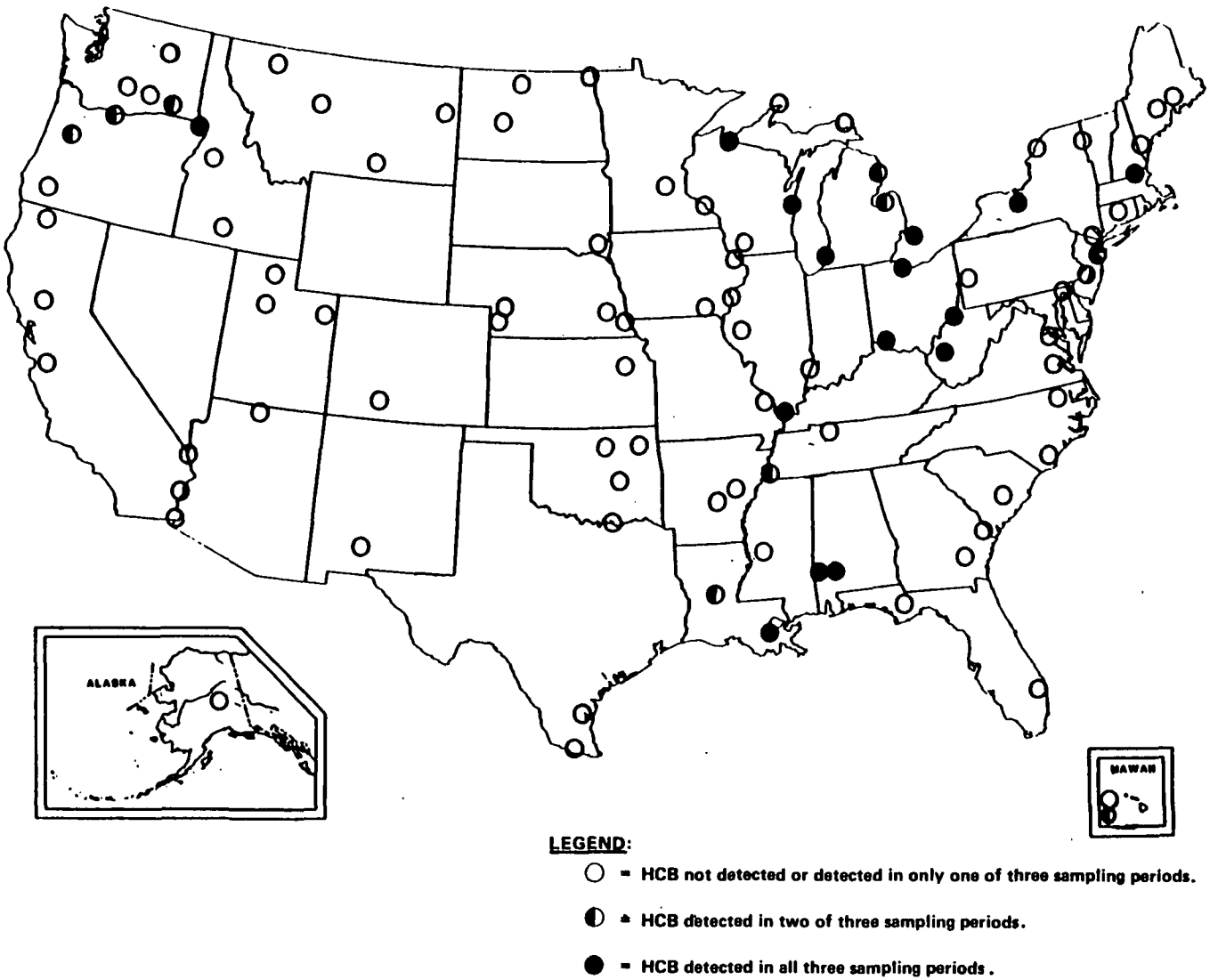


Figure 5-9. FWS national pesticide monitoring program: HCB residues in freshwater fish at 97 stations with consecutive data for the 1976-77, 1978-79, and 1980-81 surveys.

Table 5-16. FWS Fish Sampling Stations at Which HCB Was Detected in at Least Two of the Following Three Sampling Periods: 1976-1977, 1978-1979, or 1980-1981

Station	River or lake	Location	Percent detected[a]
	Stations with HCB detected in all 3 sampling periods		
15	Mississippi River	Luling, AL	100
24	Ohio River	Marietta, OH	100
53	Merrimac River	Lowell, MA	100
107	Lake St. Clair	Mt. Clemens, MI	100
21	Lake Michigan	Sheboygan, WI	80
105	Lake Michigan	Saugatuck, MI	78
59	Alabama River	Chrysler, AL	78
14	Tombigbee River	McIntosh, AL	75
108	Lake Erie	Port Clinton, OH	67
23	Kanawha River	Winfield, WV	67
18	Lake Ontario	Port Ontario, NY	62
42	Snake River	Lewiston, ID	55
22	Lake Superior	Bayfield, WI	50
69	Ohio River	Cincinnati, OH	45
70	Ohio River	Metropolis, IL	44
	Stations with HCB detected in 2 of 3 sampling periods		
76	Mississippi River	Memphis, TN	50
96	Snake River	Ice Harbor Dam, WA	50
46	Columbia River	Cascade Locks, OR	44
100	Manoa Stream	Honolulu, HI	40
20	Lake Huron	Bay Port, MI	40
106	Lake Huron	Alpena, MI	30
54	Raritan River	Highland Park, NJ	28
45	Willamette River	Oregon City, OR	22
81	Red River	Alexandria, LA	22

[a]Percent of total number of composite samples collected in the three sampling periods in which HCB was detected (detection limit is 0.01 ppm, wet-weight).

contiguous 48 states. Composite samples of 10 starlings are then prepared for chemical analysis from each site. Figure 5-10 is a map of the United States showing the locations of the starling sampling sites.

Many changes in the method of quantification for HCB occurred between 1972 and 1976. Few changes in the methods have taken place since 1976. These improvements in methodology confound comparisons among collections, although results from a particular collection can be used to assess regional differences of HCB levels (Bunck 1985).

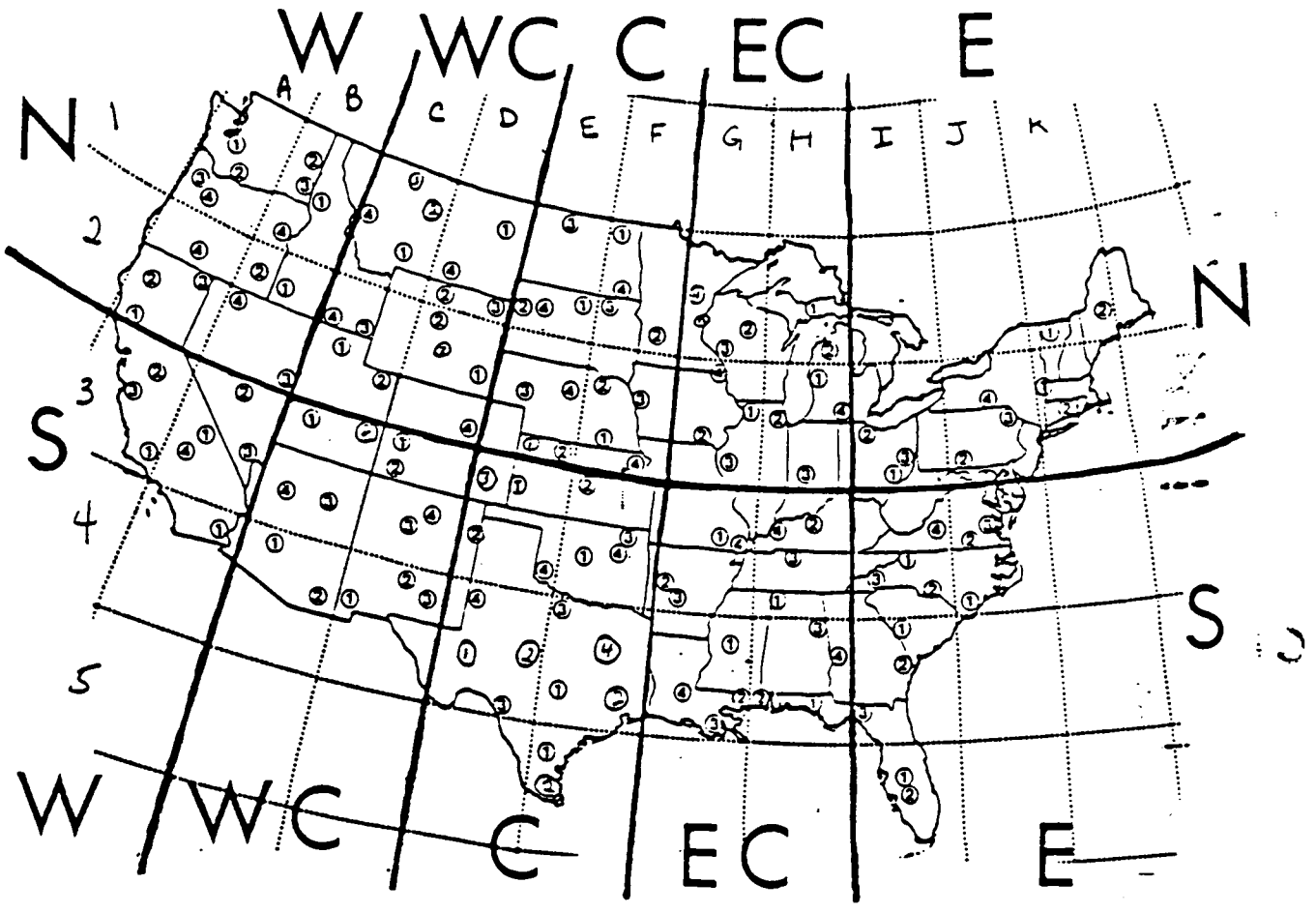
(2) Summary of results. HCB residue levels have been determined for starling collections in 1972, 1974, 1976, 1979, and 1982 (Nickerson and Barbehenn 1975, White 1976, White 1979a, Cain and Bunck 1983, and Bunck 1985 in preparation, respectively). The results of the five surveys are summarized in Table 5-17 and Figure 5-11 on a regional basis. Figures 5-12 and 5-13 are maps showing the locations of the sites where HCB was detected in each of the five survey periods.

HCB residue levels in starlings have generally been below 0.01 ppm wet-weight. The highest nationwide occurrence was 32 percent for samples from the 1972 collection. Geographical variation in the occurrence of HCB is significant in all years except 1976. The locations sampled in each collection were similar except for 1979. No starling pools from sites in Washington and Oregon were obtained in that year. Generally, HCB was detected more frequently in samples from the northwestern and southwestern regions. In 1976 and 1979, HCB was also commonly found in starling pools from the south central region (Bunck 1985).

5.3.3 FWS Monitoring Network for Waterfowl

(1) Network description. FWS began nationwide monitoring of HCB residues in the wings of hunter-killed ducks as part of the NPMP in 1972. Two duck species are monitored in this network -- the aquatic mallard (Anas platyrhynchos) and the black duck (Anas rubripes). These two species were selected because their combined range encompasses the continental United States. The mallard is relatively abundant in all but the eastern states where the black duck predominates (White and Heath 1976).

The wings used for the survey are a byproduct of an established nationwide survey of waterfowl productivity and harvest. Each fall, selected waterfowl hunters mail wings of ducks harvested during each hunting season to a collection station within each of the four major waterfowl flyways. The major flyways, depicted on the map in Figure 5-14, are corridors comprising states or parts of states in which



Source: Bunck (1985).

Grouping of 5 degree blocks to obtain regions referred to in Table 5-17. N = Northern, S = Southern, E = East, EC = East Central, C = Central, WC = West Central, W = West. Small letters and numbers represent first two characters in site codes of sample locations for starlings.

Figure 5-10. FWS national pesticide monitoring program - starling collection stations.

Table 5-17. Occurrence of HCB and Maximum Level (PPM Wet-Weight) in Starlings from the Continental United States

Region	1972[a]			1974[a]			1976			1979[a]			1982[a]		
	N[b]	Occur. (%)	Max	N	Occur. (%)	Max	N	Occur. (%)	Max	N	Occur. (%)	Max	N	Occur. (%)	Max
NORTHERN															
East	11	45	0.28	10	20	0.029	10	20	0.73	10	30	0.03	11	9	0.04
East central	13	31	0.55	12	17	0.17	13	23	0.56	13	23	0.02	13	0	ND
Central	15	0	ND[c]	15	7	0.26	16	19	0.03	15	0	ND	16	0	ND
West central	14	0	ND	13	0	ND	13	8	0.02	11	0	ND	13	0	ND
West	16	75	3.3	16	56	9.1	16	31	2.0	7	28	0.06	15	73	0.68
SOUTHERN															
East	12	17	0.014	12	8	0.24	9	33	0.20	12	33	0.41	12	17	0.02
East central	16	63	0.14	16	6	0.038	16	13	0.23	12	33	0.04	14	14	0.01
Central	12	25	0.027	12	33	0.038	12	42	0.07	11	81	0.16	14	14	0.02
West central	13	8	0.025	12	17	0.052	13	0	ND	13	0	ND	13	0	ND
West	8	50	0.037	8	38	0.042	7	0	ND	8	25	0.03	8	50	0.16
Nationwide	130	32	3.3	126	20	9.1	125	19	2.0	112	24	0.41	129	17	0.68

[a]Occurrence frequencies differ significantly among regions ($P<0.005$).
[b]Number of pools (10 samples per pool).
[c]Not detected in any samples (detection limit of 0.01 ppm wet-weight).

Source: Bunck (1985).

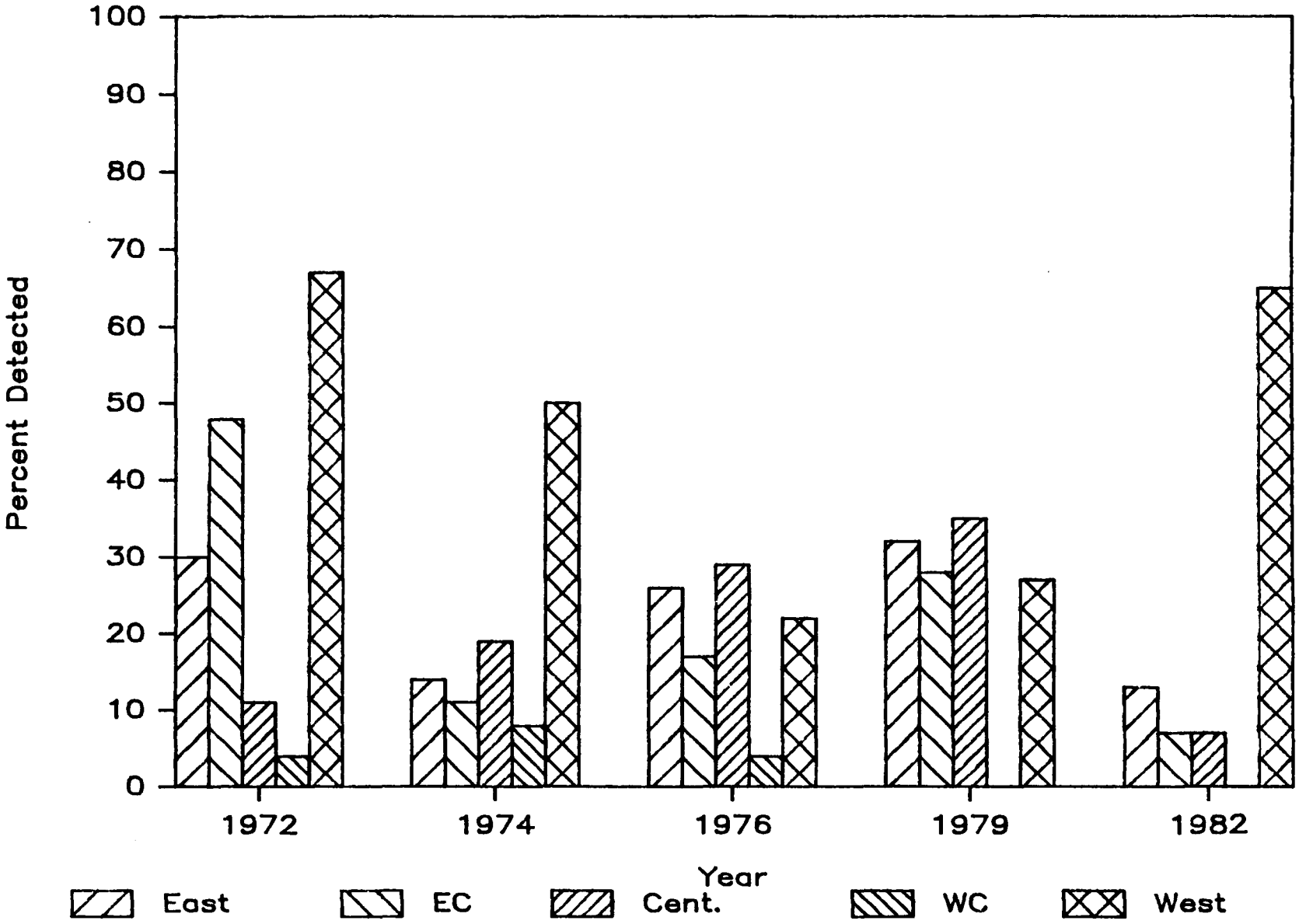


Figure 5-11. Occurrence of HCB in starlings by regions, 1972-1982.

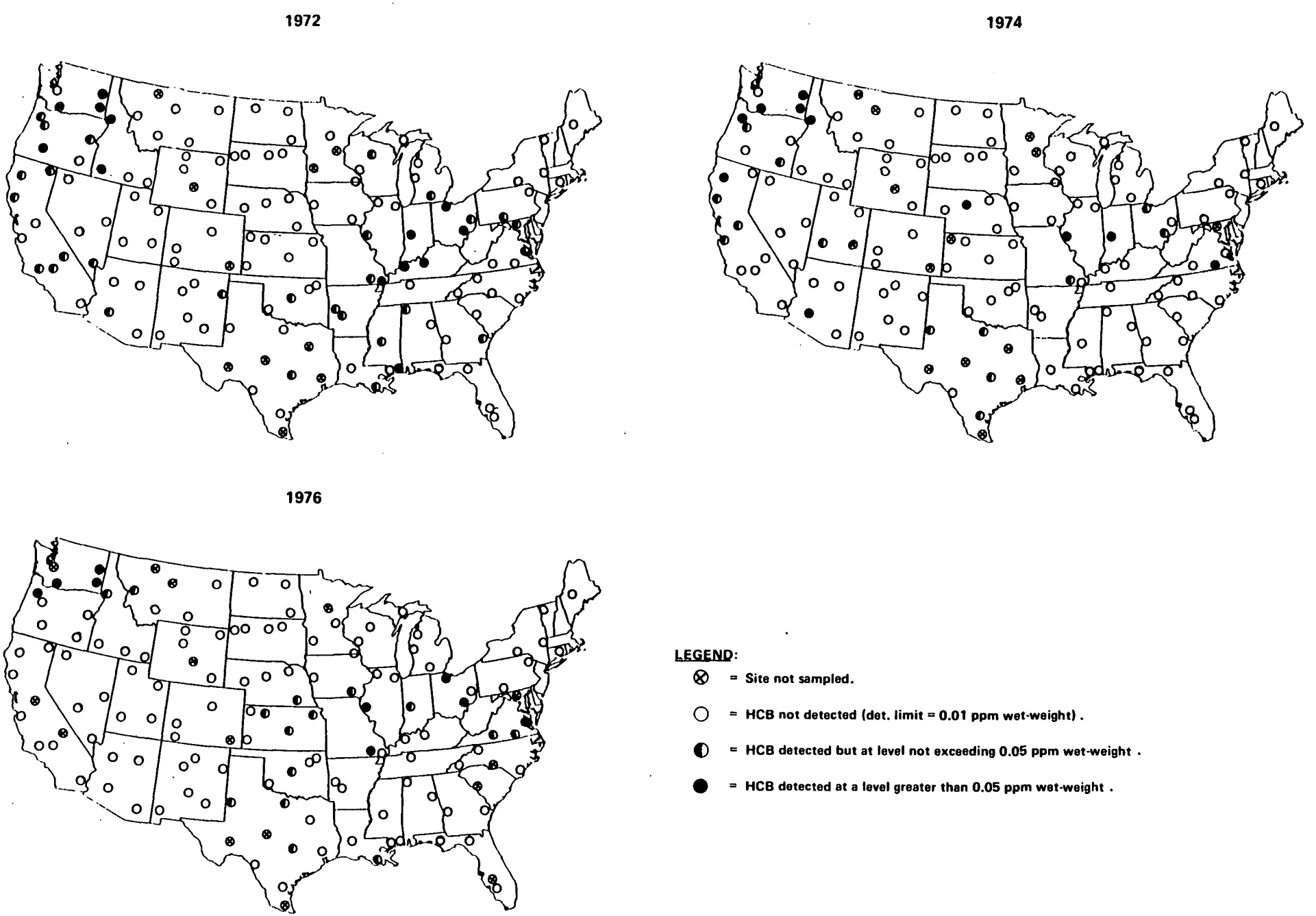
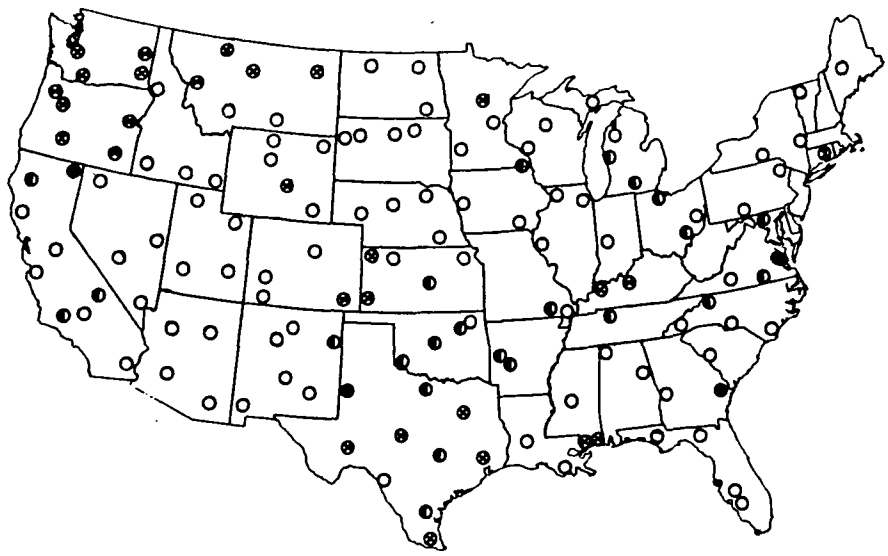
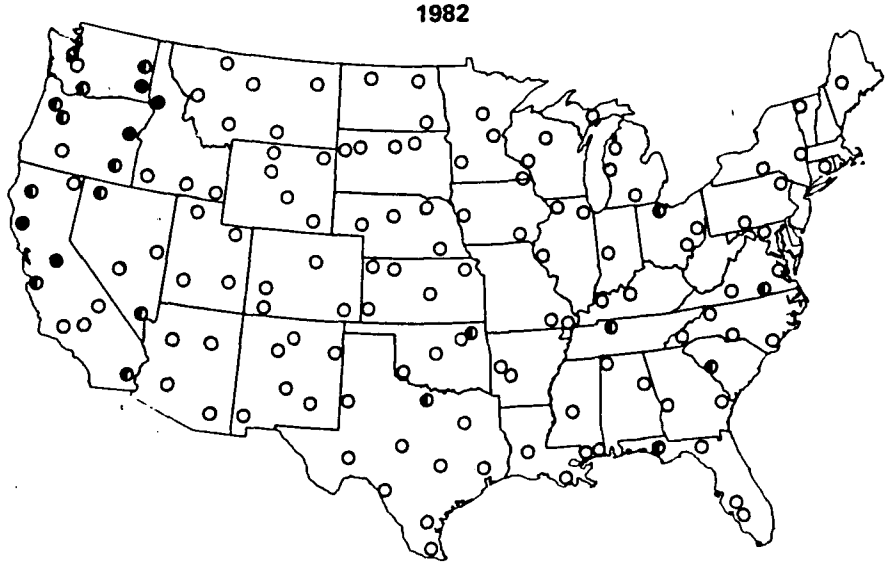


Figure 5-12. FWS national pesticide monitoring program: HCB residues in starlings, 1972-1976.

1979



1982



LEGEND:

⊗ = Site not sampled (11 sites were not sampled in 1982; the site locations are not known).

○ = HCB not detected (det. limit = 0.01 ppm wet-weight).

◐ = HCB detected but at level not exceeding 0.05 ppm wet-weight.

● = HCB detected at a level greater than 0.05 ppm wet-weight.

Figure 5-13. FWS national monitoring program: HCB residues in starlings, 1979-1982.

Figure 5-14. Major waterfowl migration flyways.

large numbers of waterfowl migrate each spring and fall (White 1979b). Wings from each state and flyway are grouped randomly in pools of 25. A subset of these composite samples is randomly selected for chemical analysis.

Many changes in the methods of quantification for HCB have occurred between 1972 and 1976. Few changes in the methods have taken place since 1976. These improvements in methodology confound comparisons among collections, although results from a particular collection can be used to assess regional differences of HCB levels (Bunck 1985).

(2) Summary of results. HCB residue levels have been determined for duck wings from the 1972-1973, 1976-1977, 1979-1980, and 1981-1982 hunting seasons (White and Heath 1976, White 1979b, Cain 1981, and Prouty and Bunck in press, respectively). The results of the four surveys are summarized in Table 5-18 and Figure 5-15 on a flyway basis.

HCB levels in duck wings have generally been below 0.01 ppm wet weight. The highest nationwide occurrence was 15 percent in wings from the 1976-1977 hunting season. The occurrence frequencies of HCB in wings from the Mississippi and Central flyways have generally been lower than those from the Atlantic and Pacific flyways. These differences were significant only in the 1972-1973 and 1979-1980 samples. Wings from the Pacific flyway had the highest occurrence frequency in the 1976-1977 and 1979-1980 samples, but in 1981-1982 the occurrence frequency in wings from the Pacific flyway was similar to that of the other flyways (Bunck 1985).

5.4 USDA National Meat and Poultry Residue Monitoring Program

5.4.1 Program Description

Since 1972, the Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA) has monitored fat samples from domestic meat and poultry for residues of HCB as part of the National Residue Monitoring Program. In addition, USDA routinely monitors HCB residue levels in imported meat and poultry products. Sampling of 17 animal production classes (hereafter referred to as "species") (see Table 5-19) is conducted at federally inspected slaughter facilities on a specific schedule to ensure that a statistically random nationwide sample is collected annually. The monitoring program is designed to ensure a 95 percent probability of detecting a chemical residue when one percent or more of a "species" presented for slaughter contains detectable levels. Figure 5-16 illustrates the five geographic regions of the United States designated by USDA for the monitoring program.

Table 5-18. Occurrence of HCB and Maximum Level (PPM Wet-Weight) in Wings of Ducks Harvested in the Continental United States

Flyway	1972 - 73[a]			1976 - 77			1979 - 80[a]			1981 - 82		
	N[b]	Occur.[c] (%)	Max	N	Occur. (%)	Max	N	Occur. (%)	Max	N	Occur. (%)	max
Atlantic	65	23	0.031	52	15	0.03	53	11	0.16	50	12	0.04
Mississippi	61	3	0.012	69	4	0.12	64	2	0.01	78	8	0.06
Central	56	7	0.014	56	11	0.03	54	4	0.03	70	1	0.01
Pacific	55	9	0.017	50	26	0.50	44	23	0.22	58	12	0.05
Nationwide	237	11	0.031	227	15	0.50	215	9	0.22	256	8	0.06

[a] Occurrence frequency differs significantly among flyways ($P<0.01$).

[b] Number of pools (25 duck wings per pool).

[c] Detection limit of 0.01 ppm wet weight.

Source: Bunck (1985).

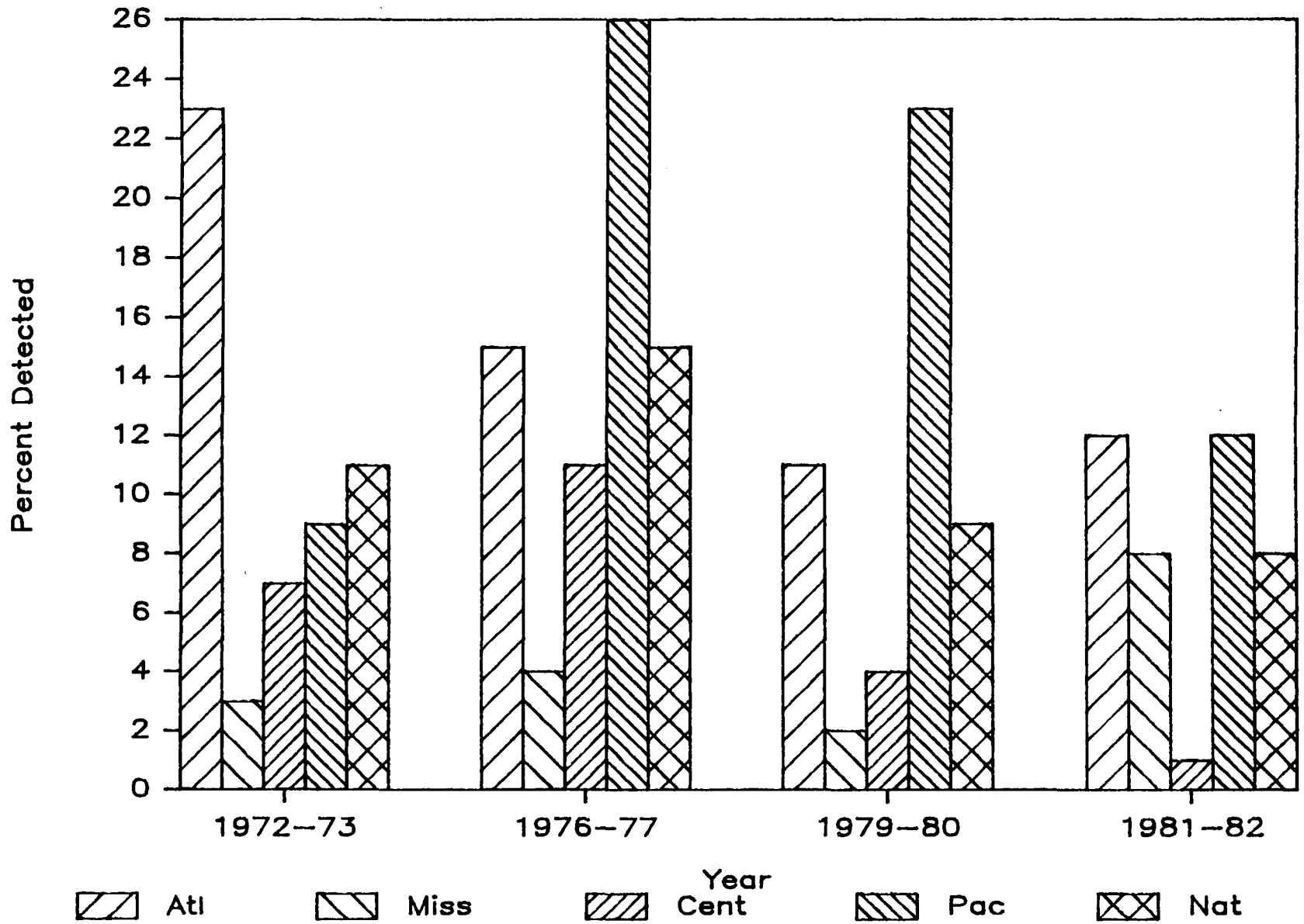


Figure 5-15. Detection frequency of HCB in ducks organized by flyway, 1972-1982.

Table 5-19. Animal Production Classes That Are Sampled by the USDA

Animal class or species
1. Bulls
2. Steers
3. Cows
4. Heifers
5. Calves
6. Sheep
7. Goats
8. Swine
9. Horses
10. Young chickens
11. Mature chickens
12. Fryer/roaster turkeys
13. Young turkeys
14. Mature turkeys
15. Ducks
16. Geese
17. Rabbits

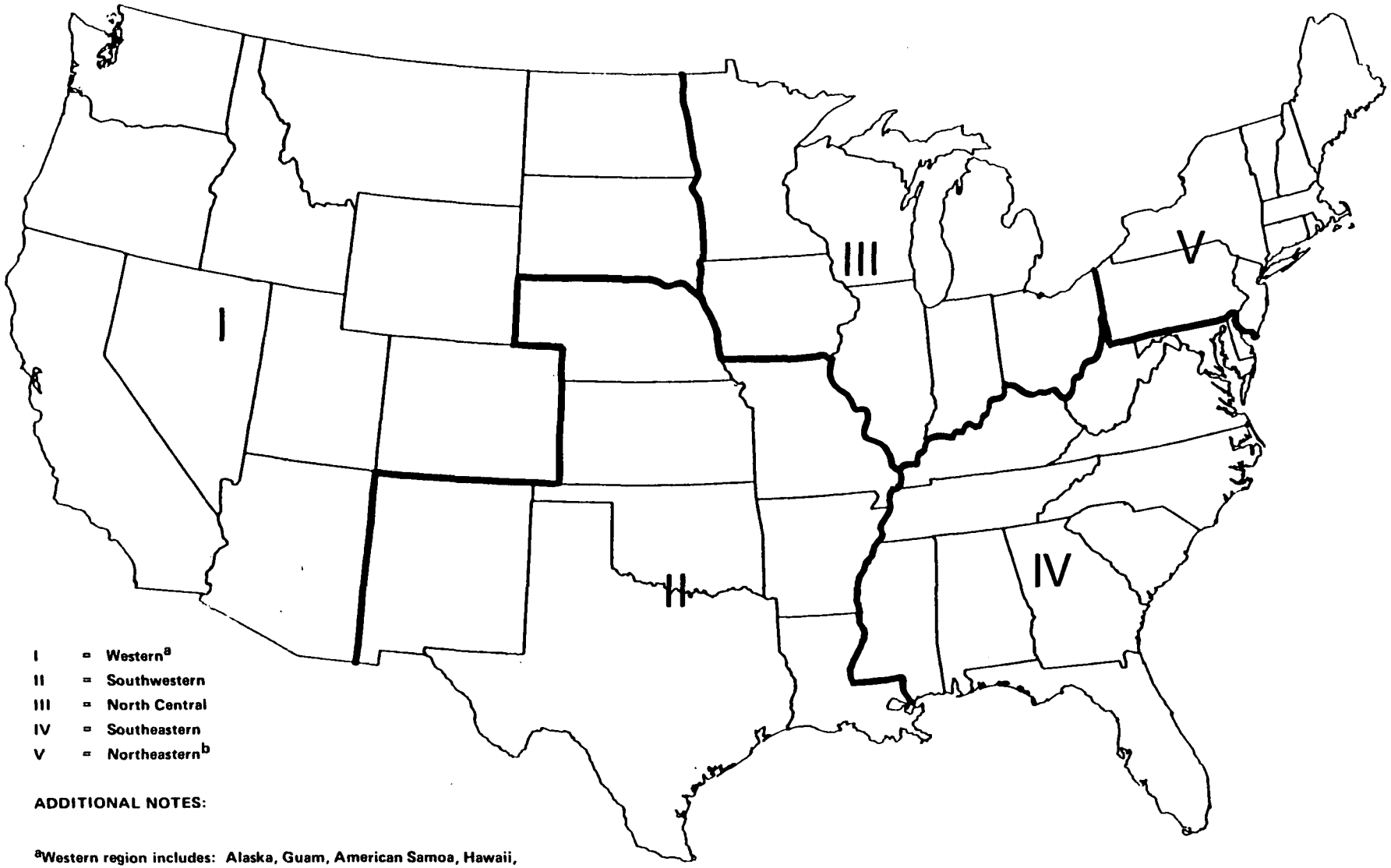


Figure 5-16. USDA meat and poultry inspection program regions.

5.4.2 Summary of Results for Domestic Meat and Poultry

(1) Temporal variability. More than 55,000 fat samples from domestic meat and poultry have been analyzed for HCB during the period 1972 to 1984. Table 5-20 summarizes, by year, the number of samples analyzed and the number of HCB detections by residue concentration interval. Similar tables summarizing the sampling results by year and by species are presented in Appendix B. The results listed in Table 5-20 indicate that HCB levels have typically been low; only 1.6 percent of the positive samples (0.2 percent of all samples) had residue levels greater than 0.10 ppm. The results do indicate, however, that the percent of positive samples rose sharply in 1974 and then fell off rapidly after 1978. Since 1980, the percent of samples containing detectable levels of HCB has remained relatively constant at three to five percent.

Figure 5-17 shows this temporal change in HCB detection frequencies on a nationwide basis over the period 1972 to 1984; it shows the annual detection frequency on both a total sample basis and a "weighted" sample basis. "Weighting" to adjust for the relative contributions of individual species to the meat and poultry food supply of the United States was done by computing for each species its relative fraction of the total poundage of dressed red meat and ready-to-cook poultry produced in the U.S. Meat and poultry production data for 1980 were arbitrarily selected as the reference data for weighting calculations (see Table 5-21). Statistical analyses (ANOVA) of the data* indicate that detection frequencies in periods 1972-73 and 1979-84 are statistically the same (assuming significance of $p = 0.05$), and they are significantly lower than the detection frequencies in period 1974-78.

Figure 5-18 shows the temporal changes in HCB detection frequency (on a total sample basis) by regions. This figure shows the same significantly higher detection frequencies during 1974-78 in every region.

Additional analyses were performed to determine whether any significant temporal differences in detection frequencies could be found for individual species or groups of species. Because the results for individual species (see Appendix B) indicate that grazing animals more frequently had detectable levels of HCB in their fat than did swine or poultry, the data were aggregated to form a grazer type (i.e., horse, bull, steer, cow, heifer, calf, sheep, and goat) and a non-grazer type (i.e., swine, young chicken, mature chicken, fryer/roaster turkey, young turkey, mature turkey, duck, goose, and rabbit). Statistical analyses of the HCB detection frequencies for these two groups (see Appendix C) and

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*See Appendix C for a more detailed description of the statistical analyses performed.

Table 5-20. USDA Residue Monitoring Program - Summary of HCB Detection Frequency in Domestic Nationwide Meat and Poultry Fat Samples

Year	Sample size	Number of samples w/detected HCB: Between 0.01 - 0.10 ppm	Between 0.11 - 0.50 ppm	Greater than 0.5 ppm	Percent of total samples w/detected HCB	Percent of weighted samples w/detected HCB[a]
1972	1,041	48	4	2	5.2	5.4
1973	2,501	155	16	3	7.0	9.7
1974	4,172	1,239	12	1	30.0	18.7
1975	4,591	1,618	14	1	35.6	20.6
1976	4,736	1,667	9	1	35.4	21.8
1977	2,316	937	4	0	40.6	23.3
1978	2,452	626	4	1	25.7	20.4
1979	4,704	381	15	1	8.4	4.6
1980	6,527	188	5	0	3.0	1.6
1981	5,374	256	10	1	5.0	2.7
1982	4,050	111	4	2	2.9	1.4
1983	6,551	277	3	3	4.3	2.1
1984	6,259	249	5	1	4.0	2.1
TOTAL	55,274	7,752	105	17		

[a]The positive HCB sample percentages are weighted by annual production rates of dressed red meat and ready-to-cook poultry (on a poundage basis). See Section 5.3.2 for details and Table 5-15 for individual species weight fractions used.

Source: Data supplied by USDA/FSIS.

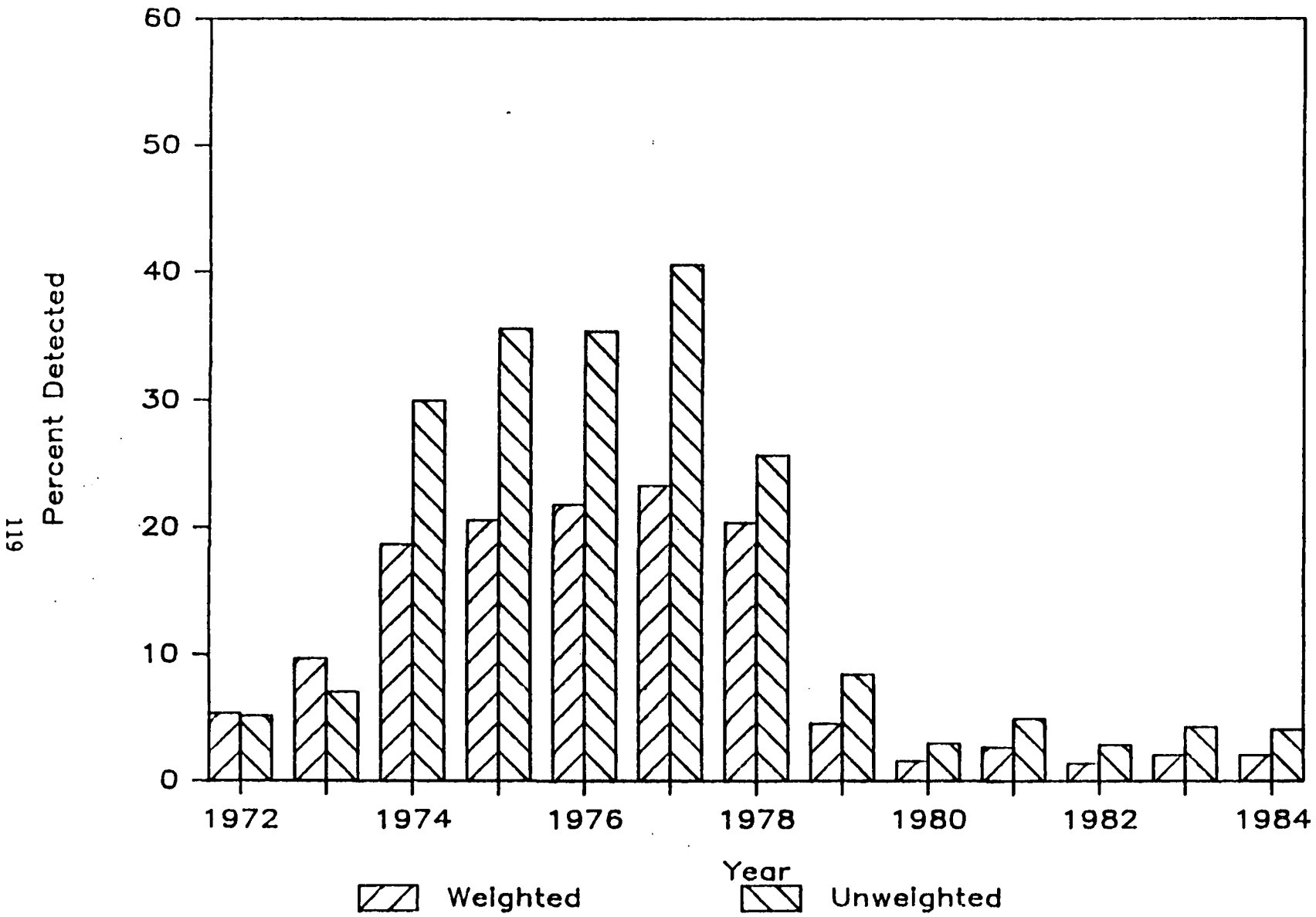


Figure 5-17. HCB detection frequency in domestic meat and poultry, 1972-1984.

Table 5-21. Relative Species Fraction of 1980 U.S. Production of Dressed Red Meat and Ready-to-Cook Poultry

Species	Fraction of 1980 production
Horse	.0040
Bulls	.0099
Steers	.2219
Cows	.0592
Heifers	.1060
Calf	.0059
Sheep	.0059
Goats	.0001
Swine	.3085
Young chickens	.2183
Mature chickens	.0125
Fryer/roaster turkeys	.0015
Young turkeys	.0441
Mature turkeys	.0004
Ducks	.0016
Geese	.0001
Rabbits	.0001
	1.0000

Sources: USDA (1981), USDA (1982).

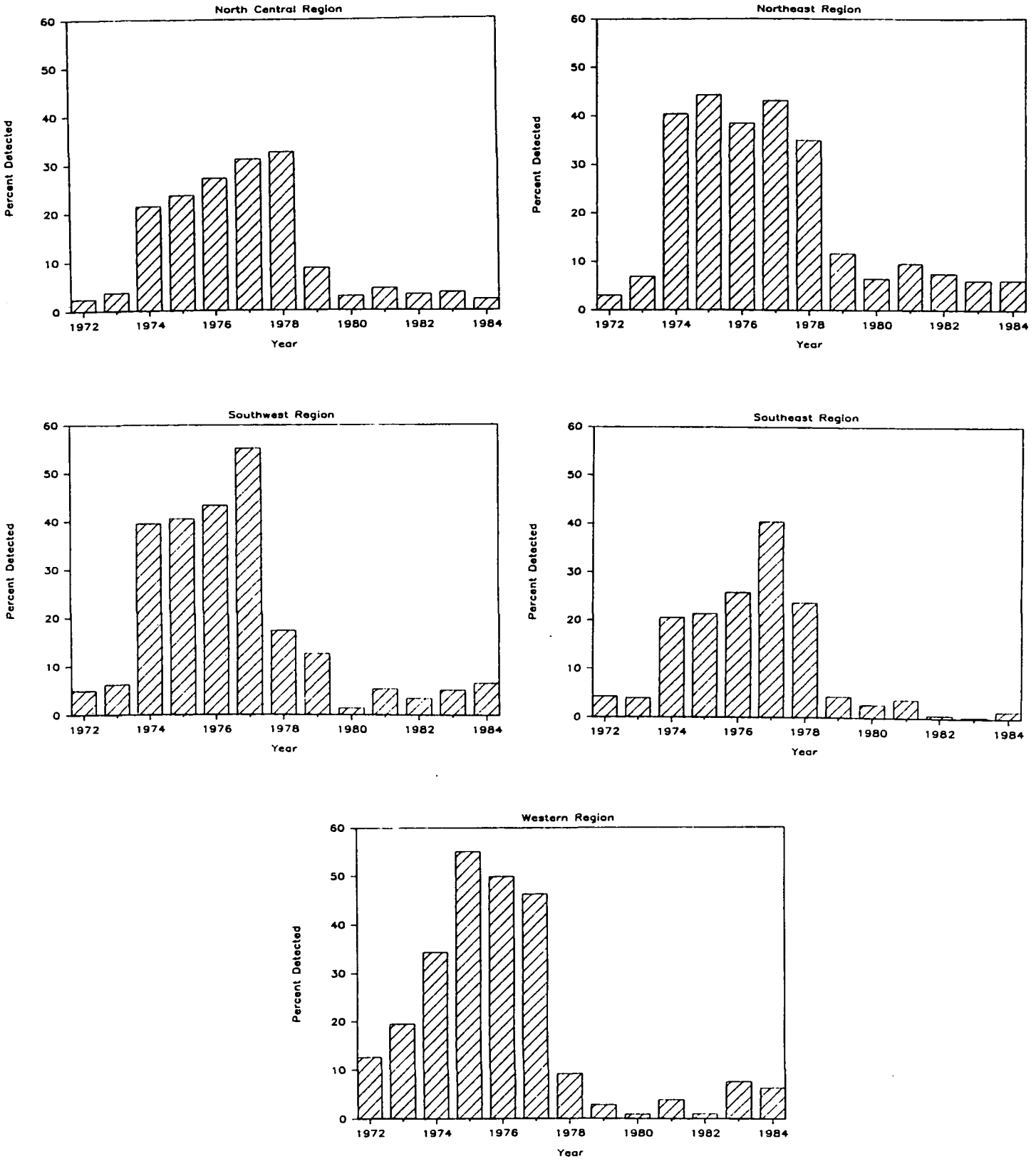


Figure 5-18. HCB detection frequency in domestic meat and poultry by USDA region, 1972-1984.

for each individual grazer species indicate a significant time effect ($p < 0.05$) over the period 1972-1984 on a nationwide basis for both groups and for each individual grazer species. Significantly higher detection frequencies were in roughly the same period (1974-1978) as was found for all species combined; however, the detection frequencies were significantly lower for the non-grazer category than for the grazer category. Figure 5-19 shows the temporal changes in detection frequency for the grazer and non-grazer groups on a nationwide basis, and Figure 5-20 shows the temporal changes on a regional basis. Appendix D contains bar graphs showing the temporal changes in detection frequencies for each grazer species and for swine, and a cumulative graph for farm poultry (young chicken, mature chicken, fryer/roaster turkey, young turkey, and mature turkey).

(2) Regional variability. Statistical analysis of the data revealed that significant regional variability exists for all species combined, grazers and nongrazers, and for most individual species.

Statistical analysis of the data for all species combined (weighted by the 1980 U.S. production of dressed red meat and ready-to-cook poultry) over the period 1972-1984 yielded a p-value of 0.0001 for regional effects (for more details on the statistical analyses, see Appendix C). In addition, the interaction between region and time was also significant ($p = 0.03$). Figure 5-21 presents a graphical comparison of the regional data by year. As can be seen from this figure, the West, Southwest, and Northeast regions generally had higher HCB detection frequencies than the Southeast and North Central regions. Re-analysis of the data after the results were grouped into three time periods (1972-1973, 1974-1978, and 1979-1984) again showed significant regional effect ($p = 0.0001$), although the interaction between region and period was only of near significance ($p = 0.0554$).

Statistical analysis of the data for individual species showed significant regional effects over the period 1972-1984 for 11 of the 17 species. The species that do not exhibit significant regional variability are bull ($p = 0.2650$), cow ($p = 0.2500$), swine ($p = 0.0927$), mature turkey ($p = 0.3873$), duck ($p = 0.1867$), and rabbit ($p = 0.3197$). Even though significant regional differences were found for most species, there was no consistent pattern in the data. Horses and calves had about the same pattern (i.e., higher than average percent detected in the North Central and Northeast regions and lower than average in the other regions). Cows had a pattern opposite to that of horses and calves (i.e., lower than average in the North Central and Northeast and higher than average elsewhere).

Statistical analysis of the data for the grazer and nongrazer groups individually and combined over the period 1972 to 1984 (Table 5-22) shows

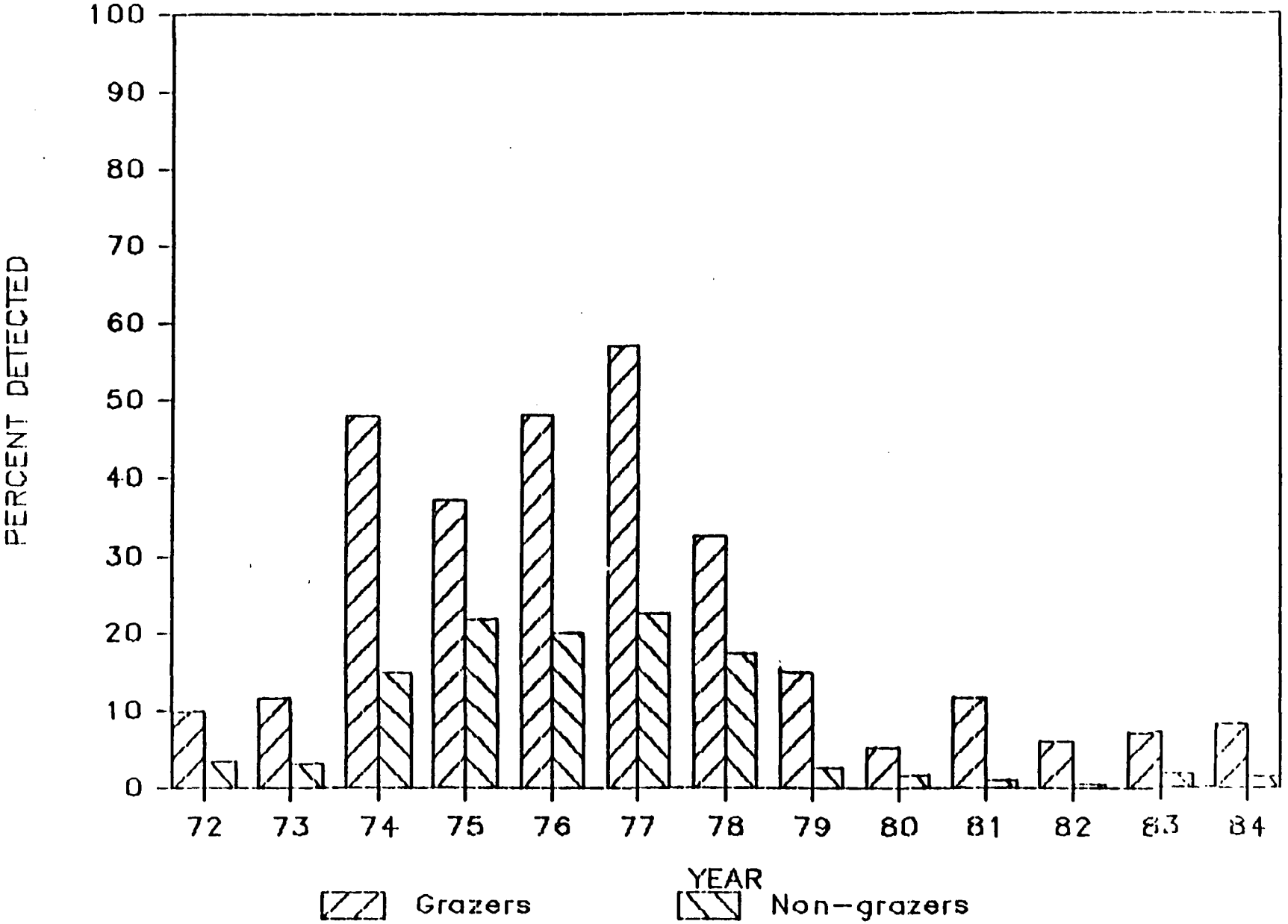


Figure 5-19. Comparison of HCB detection frequencies in grazing and non-grazing domestic animals, 1972-1984.

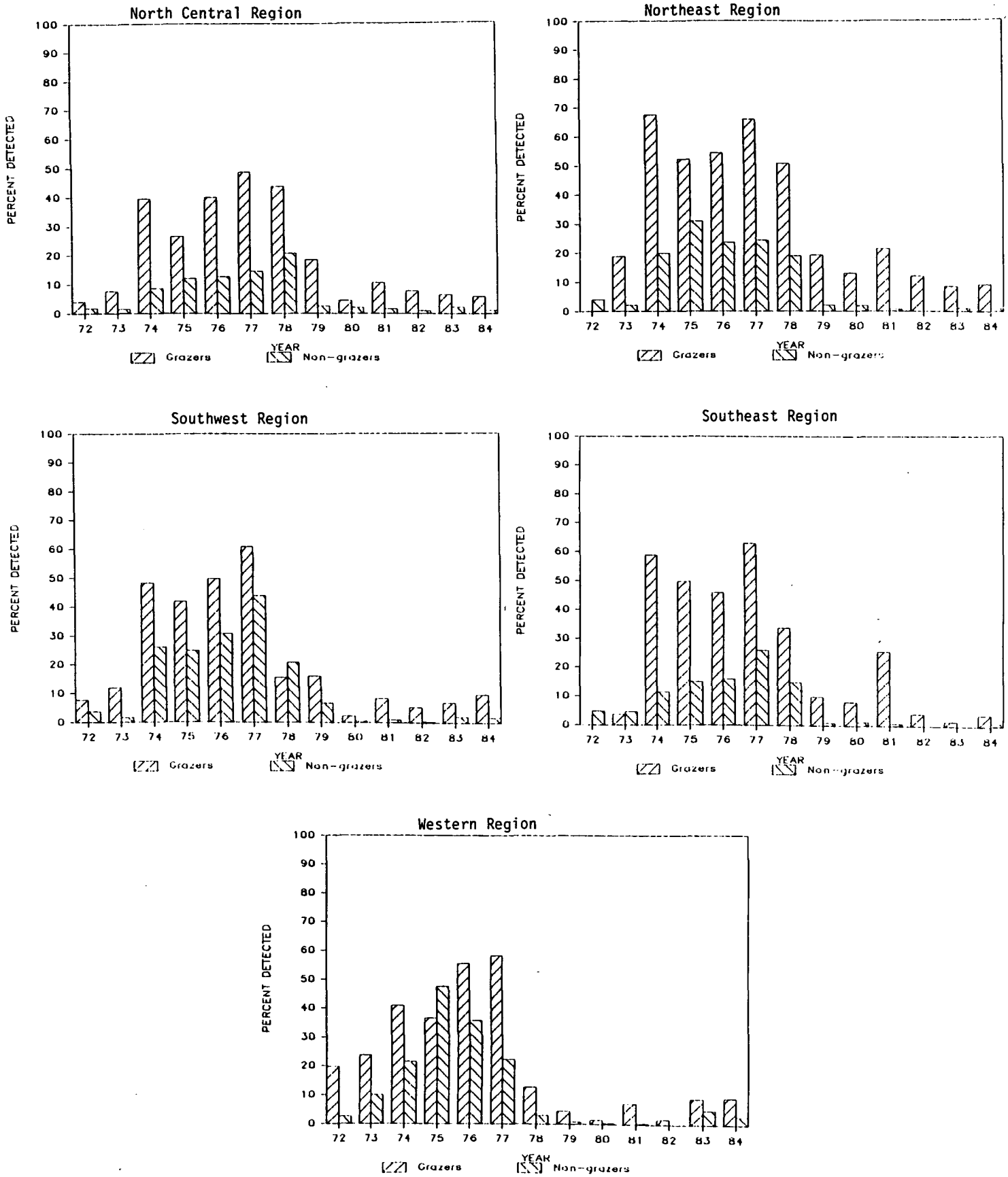


Figure 5-20. HCB detection frequency in grazing and nongrazing domestic animals by USDA region, 1972-1984.

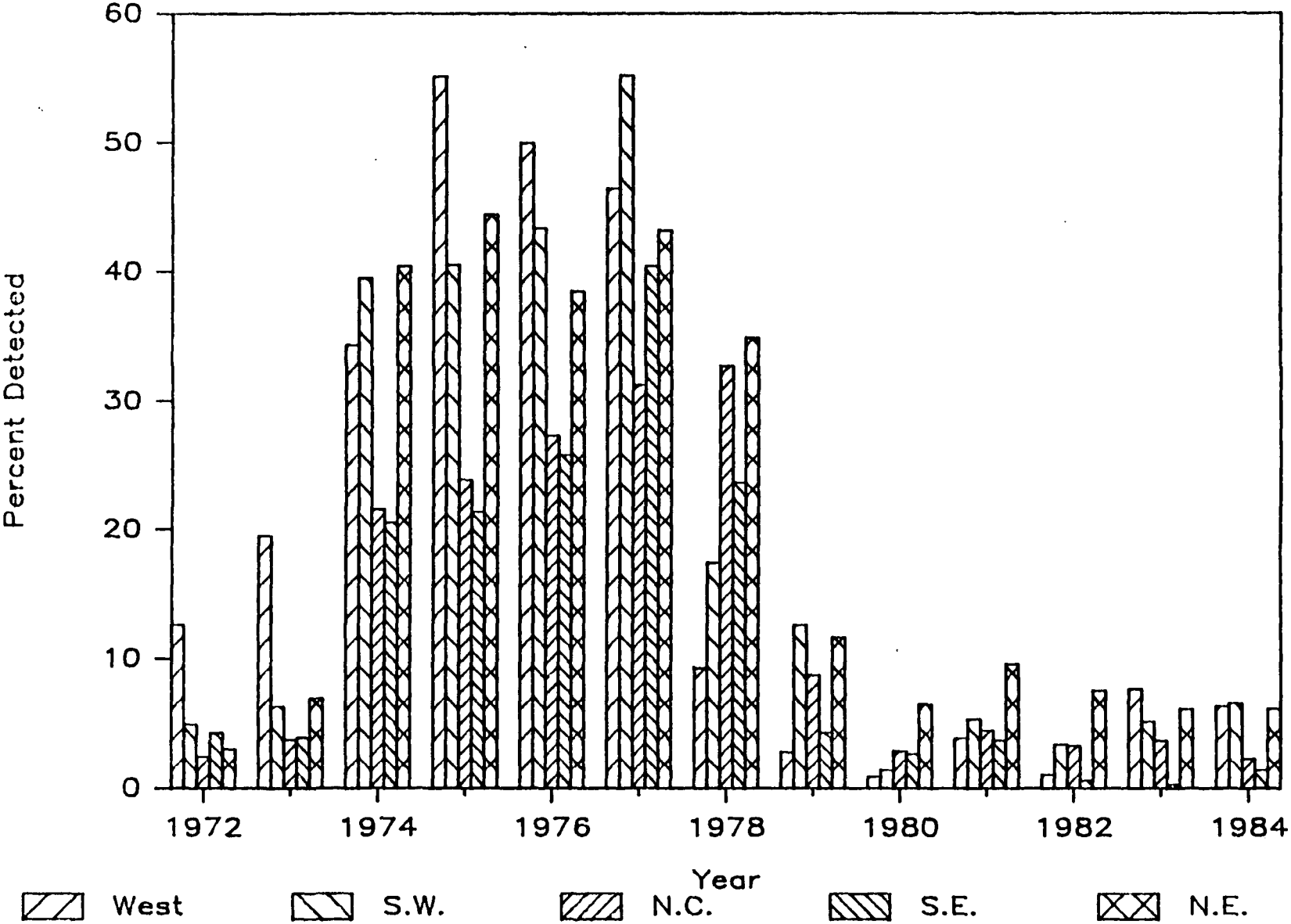


Figure 5-21. HCB detection frequency in meat and poultry, regional comparison.

a significant regional effect for grazers ($p = 0.0385$), nongrazers ($p = 0.0001$), and the combination of the two groups ($p = 0.0001$). The regional effect was also tested for the grazers and nongrazers groups over the period 1974 to 1978 (Table 5-22) and shows a significant regional effect for grazers ($p = 0.0069$), nongrazers ($p = 0.0001$), and the combination of the two groups ($p = 0.0001$).

5.4.3 Summary of Results for Imported Meat and Poultry

More than 15,000 fat samples from imported meat and poultry were analyzed for HCB by USDA during the period 1979 through June 1984. Table 5-23 summarizes, by year, the percentage of positive detections by country of origin. Figure 5-22 presents the results graphically. A table summarizing, by year, the number of samples analyzed and the number of HCB detections by residue concentration interval is presented in Appendix E. Data are not available for analyses performed prior to 1979. The results listed in Table 5-23 and Figure 5-22 show the detection frequency has steadily declined from an incidence of 15.2 percent in 1979 to 1.4 percent in 1984.

5.5 EPA NHATS Program

The following section is excerpted in large part from Mack and Mohadjer (1985) and Robinson et al. (1985). These two reports present detailed analyses of the NHATS data for HCB. The major findings of these reports are summarized in this section.

5.5.1 Program Description

The National Human Adipose Tissue Survey (NHATS) is an annual program to collect and chemically analyze a nationwide sample of adipose tissue specimens for the presence of toxic compounds. The program is administered by EPA's Office of Toxic Substances.

The NHATS program uses a statistical multi-stage sampling design to select a representative national sample of adipose tissue specimens each year. The United States is divided into four Census Regions which are further subdivided into nine Census Divisions (see Figure 5-23). The NHATS design stratifies the 48 contiguous states into the nine Census Divisions. Within each Census Division, standard metropolitan statistical areas (SMSAs) are selected with probabilities proportional to their respective populations. The number of SMSAs selected from each Census Division is determined by the Division's population relative to the entire U.S. Within each SMSA one or more hospitals and/or associated pathologists/medical examiners are identified and asked to contribute

Table 5-22. Summary of Analyses of Regional Variation in HCB Detection Frequency for the Grazer and Nongrazer Groups [a, b]

Group	West	Southwest	North central	Southeast	Northeast	p-Level
Period 1972-1984						
Grazer	High	Low	Low	Low	Low	0.0385
Nongrazer	High	High	Low	Low	High	0.0001
The two types combined	High	High	Low	Low	High	0.0001
Period 1974-1978						
Grazer	High	Low	Low	High	High	0.0069
Nongrazer	High	High	Low	Low	High	0.0001
The two types combined	High	High	Low	Low	High	0.0001

[a]For more detail on the statistical analyses (ANOVA), see Appendix C.

[b]"High," and "Low," are relative to the overall percent detected values for that particular group.

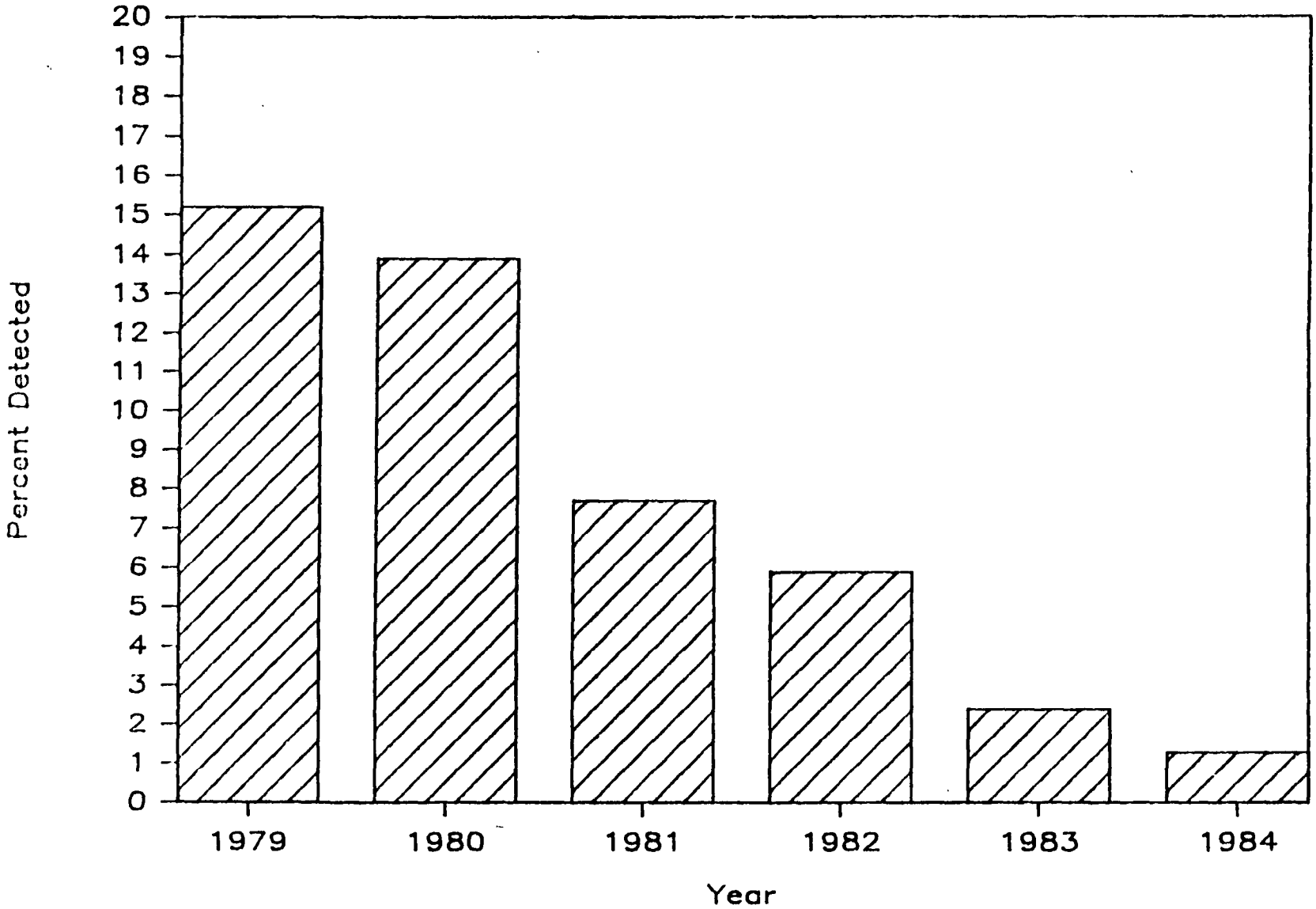


Figure 5-22. HCB detection frequency in imported meat and poultry, 1972-1984.

Table 5-23. USDA National Residue Monitoring Program Summary of HCB Detection Frequency in Imported Meat and Poultry for Calendar Years 1979 to June 30, 1984

Country	Percent of samples with detected HCB (≥0.01 ppm)[a]					
	1979	1980	1981	1982	1983	1984
Argentina	38.7	31.9	14.3	14.7	6.5	6.0
Australia	5.6	3.8	ND	2.0	1.3	1.8
Belgium	90.9	77.8	17.4	7.5	2.8	ND
Brazil	7.5	7.1	ND	3.5	ND	3.5
Bulgaria	ND	20.0	-	-	-	-
Canada	5.5	10.8	2.9	2.7	1.2	0.7
Rep. of China	-	ND	-	ND	-	-
Costa Rica	4.5	4.0	ND	2.6	ND	ND
Czechoslovakia	80.8	86.5	71.0	45.4	37.9	ND
Denmark	13.5	5.0	4.3	2.3	0.9	0.9
Dominican Rep.	13.3	ND	7.7	2.0	ND	ND
El Salvador	5.3	ND	ND	ND	ND	ND
Finland	-	-	-	-	ND	ND
France	30.8	40.9	ND	9.1	13.8	ND
Germany	9.1	ND	60.0	7.1	ND	ND
Guatemala	3.3	8.2	ND	ND	ND	ND
Haiti	7.1	ND	14.3	6.7	ND	ND
Honduras	5.2	6.9	ND	5.4	ND	ND
Hong Kong	20.0	7.1	ND	23.5	ND	ND
Hungary	8.1	9.2	ND	2.7	3.6	ND
Iceland	75.0	-	33.3	ND	ND	33.3
Ireland	5.9	25.1	14.3	19.5	5.8	2.8
Israel	-	-	100.0	ND	4.2	ND
Italy	87.5	83.3	100.0	43.8	ND	100.0
Mexico	ND	-	-	-	3.2	ND
Netherlands	48.4	33.3	13.3	15.5	ND	2.6
New Zealand	5.6	5.5	5.3	2.2	0.8	ND
Nicaragua	3.8	2.5	ND	ND	ND	ND
Panama	ND	ND	ND	ND	ND	ND
Paraguay	ND	ND	-	-	-	-
Poland	11.5	13.0	8.3	2.7	3.2	1.6
Romania	19.7	21.0	ND	9.4	ND	ND
Sweden	-	-	-	-	ND	ND

Table 5-23. (Continued)

Country	Percent of samples with detected HCB (≥0.01 ppm)[a]					
	1979	1980	1981	1982	1983	1984
Switzerland	ND	40.0	13.3	21.2	23.5	11.1
Taiwan	-	6.4	ND	ND	ND	3.4
Uruguay	39.5	7.4	12.5	ND	ND	ND
Yugoslavia	5.0	10.2	ND	ND	ND	ND
Total	15.2	13.9	7.7	5.9	2.4	1.4

ND - Not detected.

[a] Detection limit of 0.01 ppm for animal fat samples on a wet-weight basis.

Source: Data supplied by USDA/FSIS.

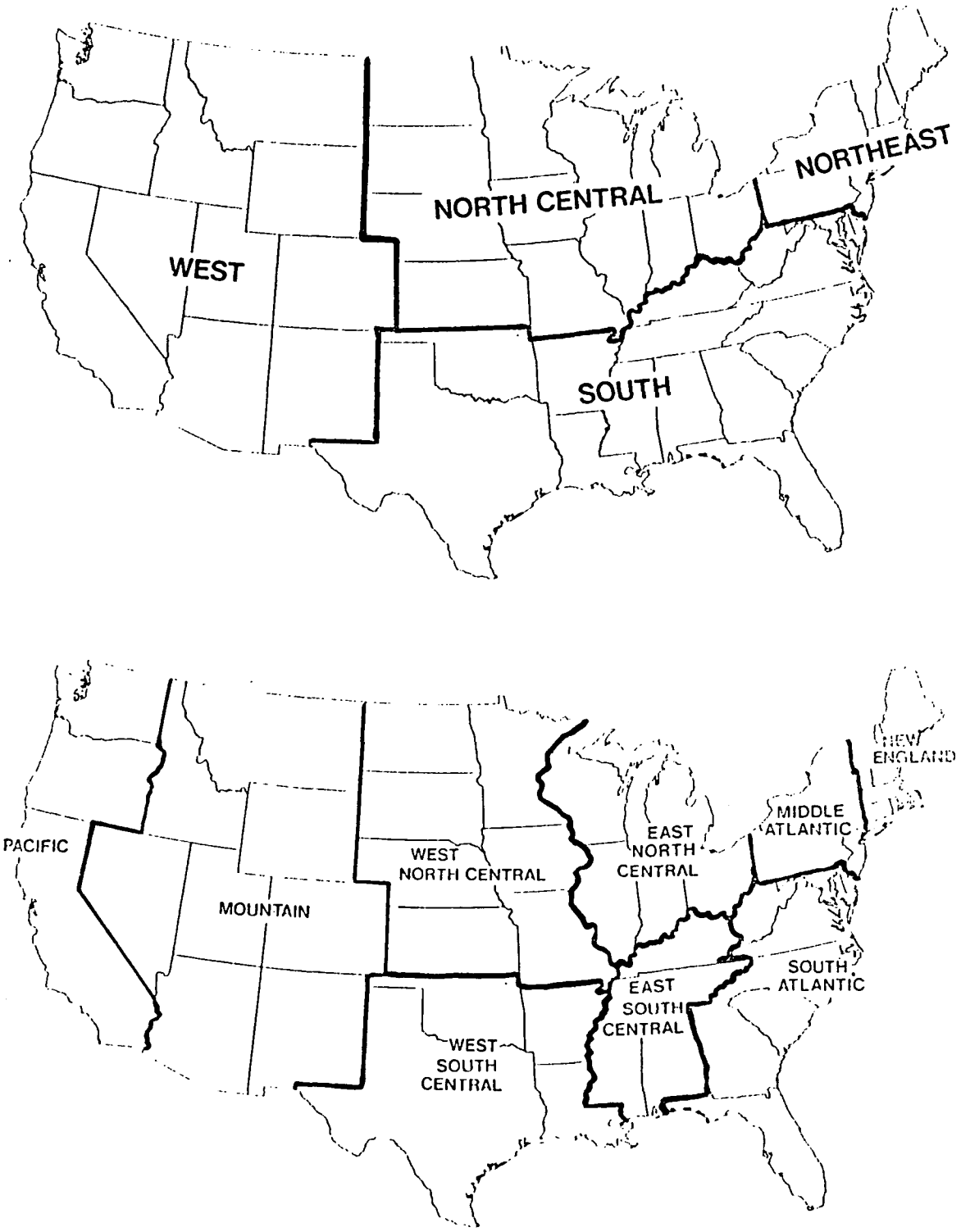


Figure 5-23. Four census regions (top) and nine census divisions (bottom) of the United States.

tissue specimens according to design specifications involving age (0-14 years, 15-44 years, and 45 + years), sex (male, female), and race (i.e. white, black, etc.) categories. The quotas are based on the corresponding age, sex, and race distributions of the Census Division to which the SMSA belongs.

5.5.2 Summary of Results

Data on HCB body burden levels are available for the years 1974 through 1983, excluding 1980 and 1982. The arithmetic mean residue level of the 6,115 specimens analyzed over this time period is 0.053 ppm and the range of values is from "not detected" to 4.33 ppm. HCB has been detected in 98.8 percent of the specimens. Table 5-24 presents summary statistics for the NHATS data.

A national time trend analysis shows that although the HCB detection frequency has been slowly increasing over time (from 97.6 percent positive in 1974 to 100 percent positive in 1983), the mean residue level exhibits a quadratic trend over time. The mean levels increase until 1979 and then decline to a 1983 average level of 0.037 ppm. Figures 5-24 and 5-25 illustrate the national time trend results for HCB detection frequencies and mean levels, respectively.

Comparisons of mean residue levels across the demographic subpopulations indicate no significant age, sex, or race differences. Overall, however, HCB levels tend to increase with age and males tend to have higher levels than females. There are significant geographic differences in mean levels with the West Census Region showing a higher mean level than the North Central and South Regions. There are no significant differences across the subpopulations with respect to HCB detection frequency.

A comparison of time trends with respect to median HCB levels across the subpopulations indicates the trends are significantly different across the age groups (the 0-14 years age group levels are constant over time, while the older age groups exhibit elevated levels in the late 1970s), but not between the sexes, race groups, or geographic regions. A comparison of time trends with respect to HCB detection frequency showed no significant differences across the subpopulations or geographic regions.

Evaluation of the upper 10th percentile of the HCB residue distribution (i.e., residue levels above 0.09 ppm) indicates no

Table 5-24 Summary Statistics for the Unweighted U.S. NHATS Data

Category	Number of specimens	Average residue level (ppm)	Standard deviation (ppm)	Geometric mean (ppm)	90th percentile (ppm)	Maximum (ppm)
Overall	6115	.05	.11	.04	.09	4.33
Sex						
Male	3070	.05	.07	.04	.10	2.83
Female	3045	.05	.13	.04	.09	4.33
Age Group						
0-14 years	1255	.06	.18	.03	.09	4.33
15-44 years	2240	.05	.09	.04	.08	3.35
45 + years	2618	.06	.07	.05	.10	2.63
Race						
White	5086	.06	.12	.04	.09	4.33
Non-white	1029	.05	.04	.04	.09	2.83
Census division						
New England	287	.05	.03	.04	.07	.23
Mid-Atlantic	1095	.07	.19	.05	.11	4.33
East North Central	1278	.05	.05	.04	.08	2.63
West North Central	439	.05	.10	.04	.07	1.99
South Atlantic	897	.04	.04	.03	.06	.61
East South Central	546	.04	.03	.03	.07	.26
West South Central	782	.06	.09	.04	.09	1.81
Mountain	311	.07	.14	.05	.10	2.23
Pacific	480	.10	.13	.08	.16	2.83

Source: Robinson et al. (1985)

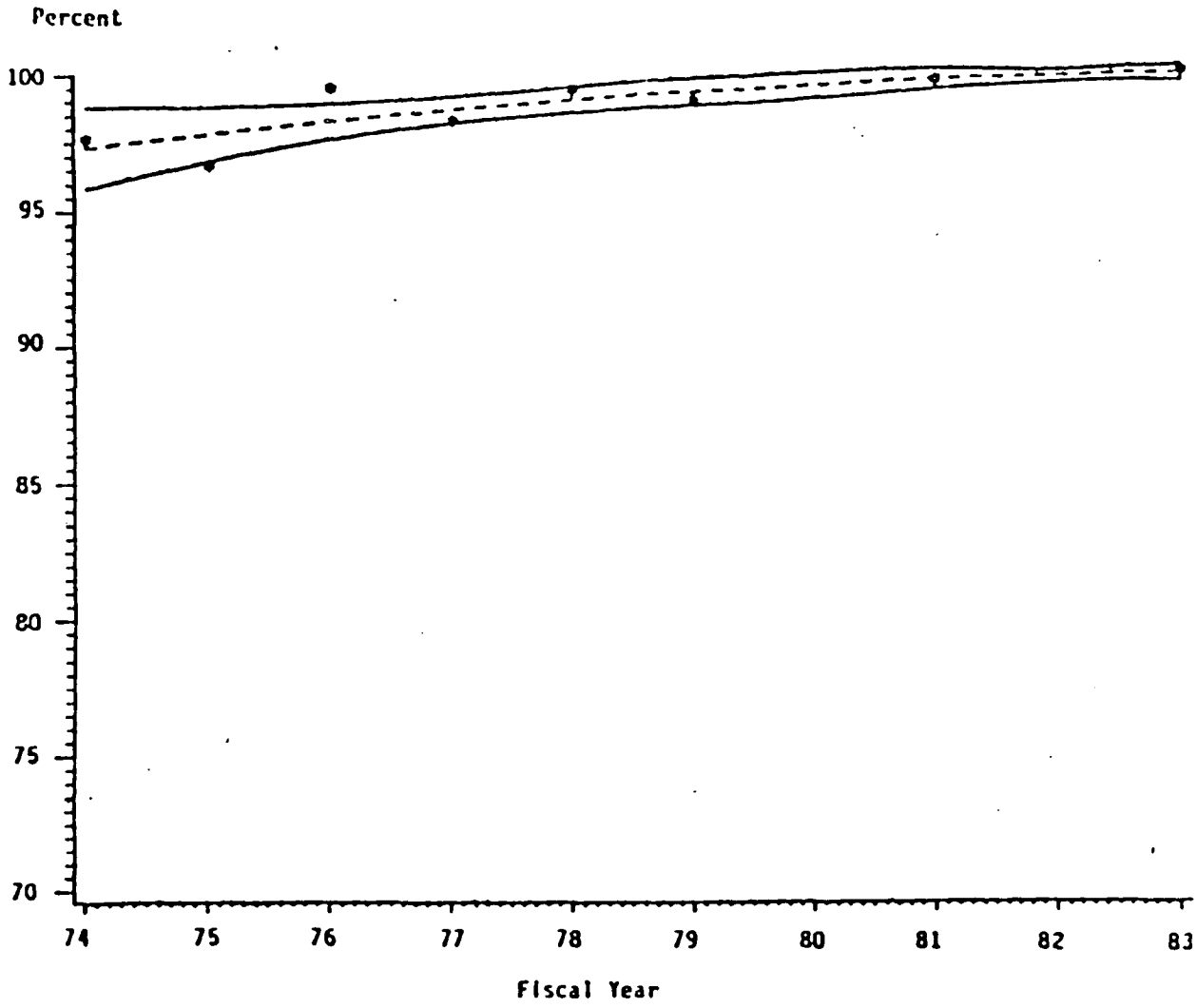


Figure 5-24. Plot of national time trend and 95 percent confidence bands for the percent of population having detectable levels of HCB.

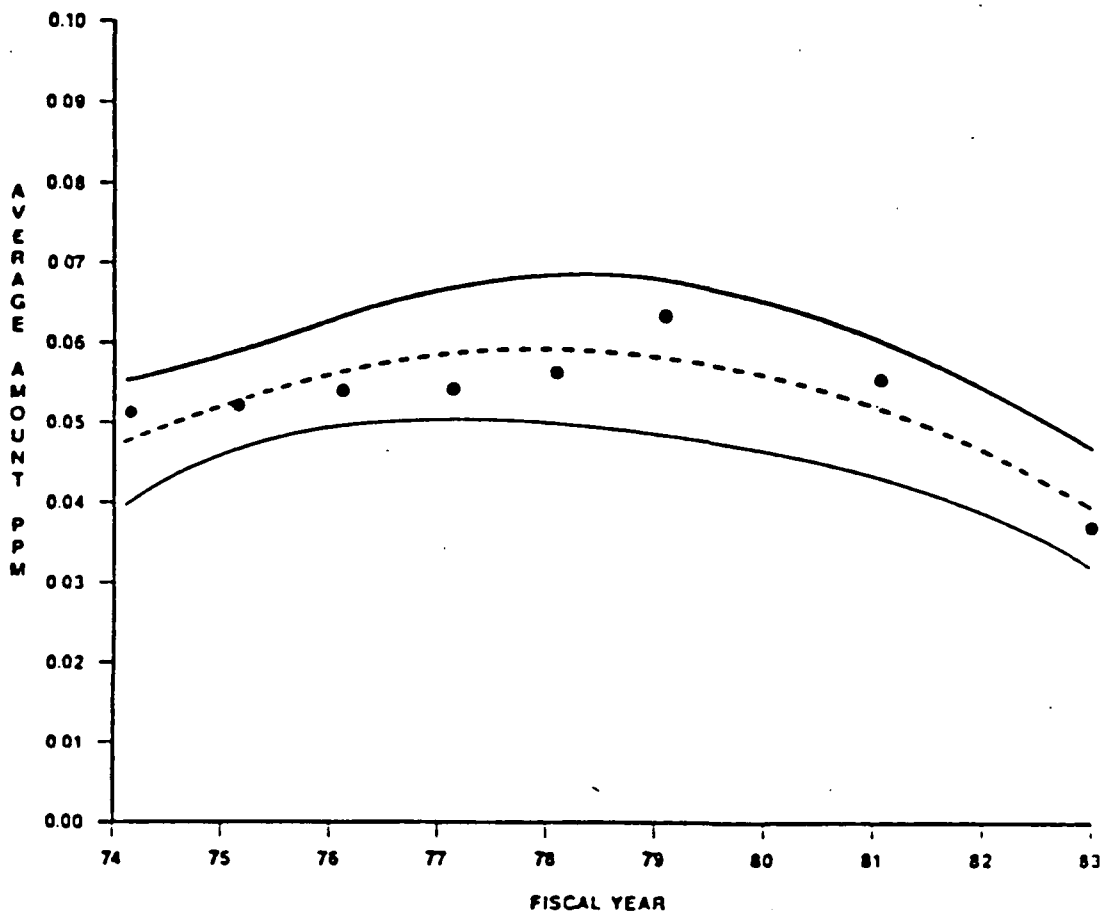


Figure 5-25. Plot of national time trend and 95 percent confidence bands for the average amount of HCB in adipose tissue from NHATS data.

significant differences; however, it does indicate differences among the Census Divisions across the three age groups. Fifty-three percent (53%) of the levels above 0.09 ppm are from the oldest age group (45+ years). This percentage varies across the Census Divisions (see Figure 5-26).

Analysis of the data also indicates that a large percentage of the specimens collected in the Pacific Census Division (38.1 percent) were above 0.09 ppm. The highest percentage for any other Census Division was 14.4 percent for the Middle Atlantic Division.

5.6 Other Monitoring Data

A considerable amount of HCB ambient monitoring data is available in the literature, mostly through university research and various national and State programs. To identify these data, a literature search was performed covering both journal articles and government publications. The information from these monitoring studies is summarized in Tables 5-25, 5-26, 5-27, and 5-28 for HCB levels in air (including occupational air), water, sediment/soil, biota, and food, respectively. Table 5-29 summarizes reported HCB concentrations in POTW sludges. These tables contain information on the number of samples, the number of detected values, the concentration, and the analytical technique, when available. For every entry, the reference and any pertinent comments are presented.

In addition to data obtained in the literature, data were also obtained from STORET (Storage and Retrieval). This is a computerized water quality data base that is operated by the U.S. Environmental Protection Agency. The data in STORET are collected by the states, EPA regions, and other government agencies (e.g., U.S. Geological Survey). In 1984, STORET was reported to have approximately 80,000,000 pieces of data (Staples et al. 1984).

Data in STORET are organized into categories describing the general sampling site. Ambient sites include streams, lakes, ponds, wells, reservoirs, canals, estuaries, and oceans. Pipe sites are industrial or municipal influents or effluents.

There are several limitations associated with the use of STORET data. The major limitation is the wide range of detection limits, sampling procedures, and overall quality of the various monitoring studies from which the data in STORET were obtained. With these

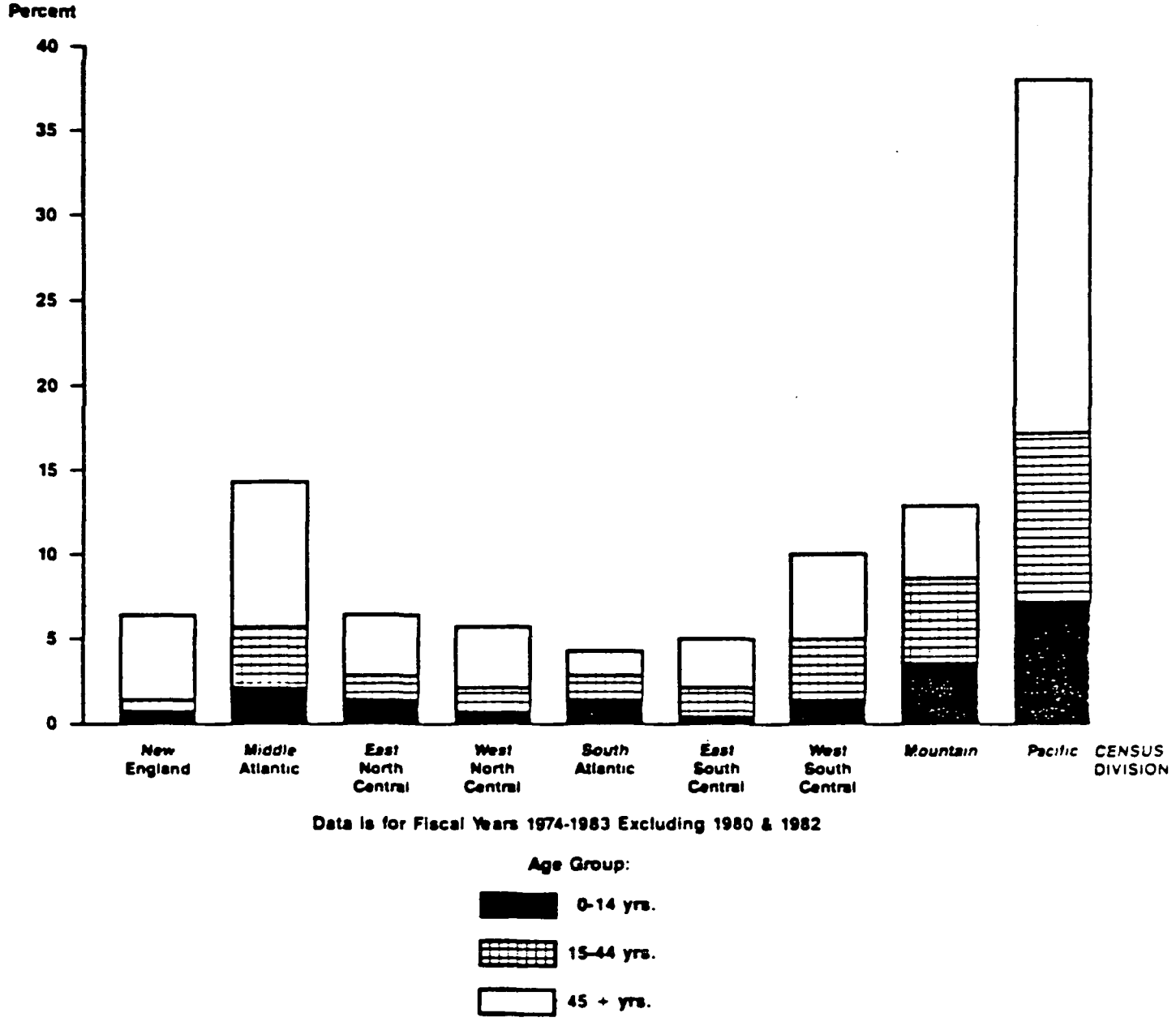


Figure 5-26. Percent of specimens above 0.09 ppm of HCB residue level by census division and age group.

Table 5-25. Summary of Air and Occupational Exposure Monitoring Data for Hexachlorobenzene

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Max	Mean	Analytical technique	Reference/comments
Ambient air							
1975/76 EPA Survey:							
-Ft. Collins, CO	14	1	ND	0.1	(0.1 ng/m3	GC/ECD	Carey et al. (1985). Detection limit of
-Harrisburg, PA	9	9	0.1	0.2	0.1 ng/m3	"	0.1 ng/m3.
-Jackson, MS	14	4	ND	0.1	(0.1 ng/m3	"	
-Lafayette, IN	9	7	ND	0.5	0.2 ng/m3	"	
1977 EPA Survey:							
-Greenville, MS	12	2	ND	45.4	4.4 ng/m3	GC/ECD	Carey et al. (1985). Detection limit of
-Pasadena, CA	12	1	ND	0.7	0.1 ng/m3	"	0.1 ng/m3.
-Wheaton, IL	10	1	ND	0.6	0.1 ng/m3	"	
1978 EPA Survey:							
-Flathead, MT	11	0	-	-	-	GC/ECD	Carey et al. (1985). Detection limit of
-Greenville, MS	12	0	-	-	-	"	0.1 ng/m3.
-Pasadena, CA	10	0	-	-	-	"	
1979 EPA Survey:							
-Cahokia, IL	11	4	ND	2.5	0.3 ng/m3	GC/ECD	Carey et al. (1985). Detection limit of
-Columbia, SC	12	0	-	-	-	"	0.1 ng/m3.
-Fresno, CA	10	5	ND	3.2	1.0 ng/m3	"	
-Harlinger, TX	11	5	ND	4.2	0.6 ng/m3	"	
-Houston, TX	11	5	ND	4.6	0.9 ng/m3	"	
-Leland, MS	12	5	ND	5.1	0.9 ng/m3	"	
-Lubbock, TX	12	3	ND	1.6	0.2 ng/m3	"	
-Pasadena, CA	10	1	ND	1.8	0.2 ng/m3	"	
-Great Lakes Basin	NA	NA	0.1	0.3	0.2 ng/m3	NA	Eisenreich et al. (1980; as reported in Eisenreich et al. 1981). Study suggests that atmospheric deposition represents a sizable, if not a major source, of organic pollutants to the Great Lakes.

Table 5-25. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
-Columbia, SC							
-August, 1978	1	1	-	-	0.40 ng/m3	GC/ECD	Billings and Bidleman (1980, 1983).
-September, 1978	3	3	0.28	0.32	0.31 ng/m3	"	High volume 24-hr.
-March, 1979	6	6	-	-	0.28 ng/m3	"	samples collected in
-May, 1979	2	2	0.21	0.25	0.23 ng/m3	"	downtown area.
-July, 1979	3	3	-	-	0.27 ng/m3	"	
-August, 1979	2	2	0.29	0.39	0.34 ng/m3	"	
-October, 1979	1	1	-	-	0.25 ng/m3	"	
-April, 1980	3	3	0.18	0.26	0.21 ng/m3	"	
-October, 1980	2	2	0.21	0.25	0.23 ng/m3	"	
-Denver, CO							
-January, 1980	9	9	0.18	0.34	0.24 ng/m3	"	Billings and Bidleman (1983). High volume 24-hr. samples collected in downtown area.
-New Bedford, MA							
-June, 1980	6	6	0.14	0.25	0.18 ng/m3	"	Billings and Bidleman (1983). High volume 24-hr. samples collected above a municipal landfill containing PCBs.
-Houston, TX	NA	NA	0.2	0.3 ng/m3	-	NA	Brooks (1984)
-Enewetak Atoll (North Pacific Ocean)	11	11	0.095	0.130	0.10 ng/m3	GC/ECD	Atlas and Giam (1981). Indicates long-range atmospheric transport of HCB, and are good measures of background concentrations.
-North Atlantic	NA	NA	-	-	0.15 ng/m3	"	Atlas and Giam (1981).
-College Station, TX	NA	NA	-	-	0.20 ng/m3	"	Atlas and Giam (1981).
-Pigeon Key, FL	NA	NA	-	-	0.12 ng/m3	"	Atlas and Giam (1981).
-E. I. duPont Company Corpus Christi, TX	10	0	ND	ND	-	GC/ECD	Li et al. (1976). Detection limit dependent on sample volume. Perc, carbon tet, and chlorine production; with onsite land disposal and deep-well injection of wastes.

Table 5-25. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
-Diamond Shamrock Deer Park, TX	24	0	ND	ND	-	"	Li et al. (1976). Perc, TCE, and chlorine production. No onsite disposal.
-Ciba-Geigy Corporation St. Gabriel, LA	14	5	ND	20 ng/m3	-	"	Li et al. (1976). Atrazine, propazine, and simazine production. No onsite disposal.
-Dow Chemical Company Pittsburg, CA	8	8	BQL	80 ng/m3	-	"	Li et al. (1976). Perc, carbon tet, and chlorine production; with onsite incineration of wastes. Detection limit of 0.02 ug/m3.
-PPG Industries Lake Charles, LA	30	13	ND	1,700 ng/m3	-	"	Li et al. (1976). Perc, TCE, VC, vinylidene chloride, chlorine, etc. production; with onsite incineration, landfill, and treatment canal for disposal of wastes.
-Olin Corporation MacIntosh, AL	24	9	ND	2,200 ng/m3	-	"	Li et al. (1976). PCNB and chlorine production; with solid wastes (in blocks) stored in open field covered with plastic.
-Stauffer Chemical Company Louisville, KY	108	108	240	7,000 ng/m3	-	"	Li et al. (1976). Perc, carbon tet, MC, chloroform, and chlorine production. No onsite disposal.
-Vulcan Materials Company Wichita, KA	180	180	530	24,000 ng/m3	-	"	Li et al. (1976). Perc, carbon tet, and chlorine production; with onsite landfill and deep-well injection of wastes.
-Darrow, LA (Baton Rouge)	NA	NA	-	16,000 ng/m3	-	NA	USEPA (1975a). Landfill receiving hex wastes from a perc plant.
Aerial fallout (dry deposition)							
-Southern California coast	5	5	0.1	3.4	1.0 ng/m2/day	GC/ECD	Young and Heesen (1976). Study indicates, since CBs are more volatile than DDT or PCBs, they are much less likely to be carried via dry particulate fallout. Fallout rates for HCB (1% that measured for DDT or 1254 PCB.

Table 5-25. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
Occupational Exposure							
1. Air							
-Dow Chemical Co. (Plaquemine, LA)	NA	NA	BQL	154,000 ng/m3	-	NA	Currier et al. (1980). Exposure (TWAs) to HCB of men employed in chlorinated solvent manufacture. Detection limit is 1 ppb.
2. Surface contact (dermal)							
-Dow Chemical Company (Plaquemine, LA)	NA	NA	3,000	124,000 ng/m2	-	NA	Currier et al. (1980). Wipe samples in non-production areas: the control room, laboratory, and clerical work areas.

NA - not available
ND - not detected
BQL - identified, but below quantification limits
GC - gas chromatography
ECD - electron capture detection
FID - flame ionization detection
MS - mass spectrometry
Perc - perchloroethylene
Carbon tet - carbon tetrachloride
TCE - trichloroethylene
VC - vinyl chloride
MC - methylene chloride
PCNB - pentachloronitrobenzene (Quinozene, Terrachlor)
CB - chlorinated benzenes
TWA - time weighted average

Note: All reported units of concentration converted to ng/m3, ng/m2, or ng/m2/day.

*Conversion of ppb to ng/m3 (based on the ideal gas law).

Table 5-26. Summary of Ambient Water and Wastewater Monitoring Data for Hexachlorobenzene

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Max	Mean	Analytical technique	Reference/comments
Ambient water							
1. Drinking water							
-Lake Ontario	3	3	6.0E-5	2.0E-4	1.0E-4 ug/l	GC/ECD	Oliver and Nicol (1982). Major sources appear to be chemical waste dump leachates and direct industrial effluents around Niagara Falls, NY. No significant difference was found before or after chlorination.
-Dade County, FL	10	4	ND	6.8E-1	1.4E-2 ug/l	GC/ECD	Barquet et al. (1981). Chlorinated municipal drinking water, from an area with extensive pesticide use, including past use of persistent organochlorines. HCB was not detected in 10 wellwater samples from the same area. Detection limit of ~6 ng/l.
-Region V	83	2	0.004	0.006 ug/l	-	NA	USEPA (1975b). Samples of raw and finished water collected from 83 utilities between January and March 1975. HCB was detected in 3 of the 83 water samples (6, 6, and 10ng/l).
-Nationwide	96	0	ND	-	-	GC/MS	Boland (1981). Samples of both raw and finished water from 96 locations. Quantification limit of 0.2 ug/l.

Table 5-26. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Concentration Mean	Analytical technique	Reference/comments
2. Surface water							
-Lake Ontario	5	5	2.0E-5	1.0E-4	6.0E-5 ug/l	GC/ECD	Oliver and Nicol (1982). Refer to comments on drinking water.
-Lake Huron	5	5	2.0E-5	1.0E-4	4.0E-5 ug/l	"	Oliver and Nicol (1982).
-Lake Ontario western basin (Niagara-on-the-Lake, at the mouth of the Niagara River)	13	NA	-	-	8.0E-4 ug/l	"	Fox et al. (1983). Study compares data from upper reaches of the Niagara R. to the western basin of L. Ontario. Indicates that the Niagara R. is the major source of HCB to the lake, from past and present industrial activity in the area.
-Niagara River at Ft. Erie (upper reach)	4	NA	-	-	2.0E-5 ug/l	"	Fox et al. (1983).
-Lower Niagara River (Niagara-on-the-Lake)	75	71	-	-	8.0E-4 ug/l	"	Kuntz and Warry (1983). HCB enters the river system from industrial waste inputs and chemical waste dump sites.
-Niagara River	NA	NA	2.0E-5	1.7E-2 ug/l	-	"	Oliver and Nicol (1982). Sampling sites along the lenth of the river. Highest value was from sample below a waste disposal site in Niagara Falls, NY.
-Niagara River (upper and lower reaches)	NA	NA	ND	BQL	-	NA	Kauss (1983). Below detection limit of 1 ng/l. Potential sources are the 215 industrial and municipal discharges and land disposal sites in Buffalo, Tonawanda, and Niagara Falls, NY.

Table 5-26. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
-Mississippi River (Baton Rouge to below New Orleans, LA)	29	NA	BQL	90.3	(2 ug/l	GC/ECD	Laska et al. (1976). Collections of samples at 5 mile intervals. This section of river contains numerous large chemical plants, having HCB as one of their byproducts. Detection limit of 0.7 ug/l.
-Wolf River (Memphis, TN)	90	NA	-	-	A: 5.4E-3 ug/l B: 1.61E-2 ug/l	NA	Jaffe et al. (1982). Mean values, at points above (A) and below (B) waste dump site. Point source of HCB is the North Hollywood site. The pesticide industry, among others, used this site (ca 20 years old, now closed) for waste disposal. Site is ca 5 km upstream of confluence with Mississippi River.
-Nueces Estuary/Corpus Christi Bay, TX (marine environment)	21	NA	BQL	6.1E-4	2.4E-4 ug/l	GC/ECD or FID	Ray et al. (1983a). Major potential sources are the numerous industrial plants, mainly petrochemical, located along the Tule Lake Channel and Corpus Christi Bay. Detection limit is 0.01 ng/l.
-San Luis Pass, TX (marine environment)	NA	NA	ND	ND	-	GC	Murray et al. (1981). West Galveston Bay. Detection limit of 0.1 ng/l.
3. Ground water (well)							
4. Precipitation							
-Great Lakes Basin	NA	NA	1.0E-3	4.0E-3	2.0E-3 ug/l	NA	Eisenreich et al. (1980; as reported in Eisenreich et al. 1981). Wet deposition of airborne organics is suggested as a major source to the Great Lakes.
-Enewetak Atoll (North Pacific Ocean)	16	NA	-	)3.0E-5 ug/l	-	GC/ECD	Atlas and Giam (1981). Indicates long-range atmospheric transport of HCB, and are good measures of background ambient values.

Table 5-26. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Max	Mean	Analytical technique	Reference/comments
-Isle Royale (Lake Superior)	3	-	-	-	0.1 ng/l	GC/ECD	Strachan et al. (1985).
"	3	-	-	-	0.01 ng/l	GC/ECD	"
"	3	-	-	-	ND	GC/ECD	"
-Caribou Island (Lake Superior)	3	-	-	-	ND	GC/ECD	"
"	3	-	-	-	0.01 ng/l	GC/ECD	"
"	3	-	-	-	0.02 ng/l	GC/ECD	"
"	3	-	-	-	0.4 ng/l	GC/ECD	"
"	3	-	-	-	ND	GC/ECD	"
							Strachan et al. (1985). Also included were estimates of rainfall loadings of HCB Volume weighted rain conc. 0.075 ng/l. Loadings from rain and snow 3.7 kg/yr. Previous estimates: rain 130 kg/yr, dryfall 1,600 kg/yr.
Wastewater							
1. Industrial							
-Ciba-Geigy Corporation St. Gabriel, LA	2	0	ND	ND	-	GC/ECD	Li et al. (1976). Refer to comments on ambient air for information on sources (see Table 5-25). Detection limit of 0.005 to 0.01 ug/l, dependent on sample volume.

Table 5-26. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
-Diamond Shamrock Deer Park, TX	2	1	ND	0.1 ug/l	-	GC/ECD	Li et al. (1976).
-Linden Chlorine Linden, NJ	6	1	ND	0.34 ug/l	-	"	Li et al. (1976).
-E. I. duPont Inc. Corpus Christi, TX	7	NA	ND	2.8 ug/l	-	"	Li et al. (1976).
-PPG Industries Inc. Lake Charles, LA	7	6	ND	7.1 ug/l	-	"	Li et al. (1976).
-Stauffer Chemical Company Louisville, KY	6	6	0.2	35 ug/l	-	"	Li et al. (1976).
-Olin Corporation MacIntosh, AL	10	7	ND	160 ug/l	-	"	Li et al. (1976).
-Vulcan Materials Company Wichita, KS	4	4	0.009	300 ug/l	-	"	Li et al. (1976).
2. Municipal							
-Lakes Ontario/Huron	4	4	1.0E-3	2.0E-3	1.5E-3 ug/l	GC/ECD	Oliver and Nicol (1982).
-Los Angeles County, CA (JWPCP)	NA	NA	2.0E-4	4.0E-4 ug/l	-	GC/ECD or MS	Young and Heesen (1976). EPA-sponsored of chlorinated pesticide levels in major municipal wastewaters of southern California. Indication of importance of surface runoff as a source of CBs to coastal ecosystems.
-Los Angeles City, CA:							
5-mile plant	NA	NA	1.0E-5	1.0E-4 ug/l	-	"	Young and Heesen (1976).
7-mile plant	NA	NA	4.1E-4	6.8E-3 ug/l	-	"	Young and Heesen (1976).
-Orange County, CA	NA	NA	7.0E-6	4.0E-5 ug/l	-	"	Young and Heesen (1976).
-San Diego City, CA	NA	NA	1.0E-5	1.0E-5 ug/l	-	"	Young and Heesen (1976).
-Oxnard	NA	NA	4.0E-5	4.0E-4 ug/l		"	Young and Heesen (1976).

Table 5-26. (continued)

NA - not available
ND - not detected
BQL - identified, but below quantification limits
GC - gas chromatography
ECD - electron capture detection
FID - flame ionization detection
MS - mass spectrometry
HCB - hexachlorobenzene
CB - chlorinated benzenes

Note: All reported units of concentration are converted to ug/l.

Table 5-27. Summary of Sediment/Soil Monitoring Data for Hexachlorobenzene

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
Sediment/soil							
1. Suspended sediment							
-Niagara River at Ft. Erie (upper reach)	NA	NA	-	-	0.005 ug/g	GC/ECD	Fox et al. (1983). Dry weight samples. Collected with 125 um plankton net.
-Lake Ontario western basin (Niagara-on-the-Lake, at the mouth of the Niagara R.)	17	17	0.015	0.460	0.108 ug/g	"	Fox et al. (1983). Dry weight samples. Collected with 125 um plankton net, size fractionated by wet sieving, 75 to 700 um particles, before analysis. Range for all sizes of particles given.
-Lower Niagara River	70	70	-	-	0.124 ug/g	GC/ECD	Kuntz and Warry (1983). Dry weight basis.
-Upper Niagara River	NA	NA	ND	-	0.030 ug/g	NA	Kauss (1983). Dry weight basis.
-Lower Niagara River	NA	NA	0.0052	-	0.097 ug/g	NA	Kauss (1983). Dry weight basis.
2. Bottom sediment							
-Lake Ontario western basin (Niagara-on-the-Lake, at the mouth of the Niagara R.)	9	9	0.062	0.840	0.220 ug/g	GC/ECD	Fox et al. (1983). Dry weight basis. Study compares concentrations found in sediment to biota. Refer to comments on aquatic biota, i.e., oligochaetes, amphipods, mysids, and fish (see Table 5-28).
-Lake Ontario	11	11	0.009	0.320	0.097 ug/g	"	Oliver and Nicol (1982). Surficial sediment samples. Refer to comments on drinking water (see Table 5-26).
-Lake Erie	5	5	7.0E-4	0.012	0.003 ug/g	"	Oliver and Nicol (1982).
-Lake Huron	42	42	4.0E-4	0.005	0.002 ug/g	"	Oliver and Nicol (1982).
-Lake Superior	13	13	2.0E-5	7.0E-4	2.0E-4 ug/g	"	Oliver and Nicol (1982).
-Lake/ o (Niag sin)	NA	NA	0.270	0.460 ug/g		"	Oliver and Nicol (1982). 0-1 and 1-2 cm depth core samples, representing deposition from 1976-1980 and 1971-1976, respectively.

Table 5-27. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Max	Mean	Analytical technique	Reference/comments
Sediment/soil							
1. Suspended sediment							
-Niagara River at Ft. Erie (upper reach)	NA	NA	-	-	0.005 ug/g	GC/ECD	Fox et al. (1983). Dry weight samples. Collected with 125 um plankton net.
-Lake Ontario western basin (Niagara-on-the-Lake, at the mouth of the Niagara R.)	17	17	0.015	0.460	0.108 ug/g	"	Fox et al. (1983). Dry weight samples. Collected with 125 um plankton net, size fractionated by wet sieving, 75 to 700 um particles, before analysis. Range for all sizes of particles given.
-Lower Niagara River	70	70	-	-	0.124 ug/g	GC/ECD	Kuntz and Warry (1983). Dry weight basis.
-Upper Niagara River	NA	NA	ND	-	0.030 ug/g	NA	Kauss (1983). Dry weight basis.
-Lower Niagara River	NA	NA	0.0052	-	0.097 ug/g	NA	Kauss (1983). Dry weight basis.
2. Bottom sediment							
-Lake Ontario western basin (Niagara-on-the-Lake, at the mouth of the Niagara R.)	9	9	0.062	0.840	0.220 ug/g	GC/ECD	Fox et al. (1983). Dry weight basis. Study compares concentrations found in sediment to biota. Refer to comments on aquatic biota, i.e., oligochaetes, amphipods, mysids, and fish (see Table 5-28).
-Lake Ontario	11	11	0.009	0.320	0.097 ug/g	"	Oliver and Nicol (1982). Surficial sediment samples. Refer to comments on drinking water (see Table 5-26).
-Lake Erie	5	5	7.0E-4	0.012	0.003 ug/g	"	Oliver and Nicol (1982).
-Lake Huron	42	42	4.0E-4	0.005	0.002 ug/g	"	Oliver and Nicol (1982).
-Lake Superior	13	13	2.0E-5	7.0E-4	2.0E-4 ug/g	"	Oliver and Nicol (1982).
-Lake Ontario (Niagara basin)	NA	NA	0.270	0.460 ug/g	-	"	Oliver and Nicol (1982). 0-1 and 1-2 cm depth core samples, representing deposition from 1976-1980 and 1971-1976, respectively.

Table 5-27. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
-Upper Niagara River	NA	NA	ND	-	3 ug/g	NA	Kauss (1983). Dry weight, mean values.
-Lower Niagara River	NA	NA	-	-	55 ug/g	NA	Kauss (1983). Dry weight, mean values.
-Niagara River Watershed (Niagara Falls, NY)	3	3	8	30	16 ug/g	GC/MS	Elder et al. (1981). Sample sites adjacent to 3 hazardous waste disposal areas: 102nd Street dump, Hyde Park landfill, and an industrialized complex with several dumpsites on the property. Detection limit of 0.5 ug/g.
-E. I. duPont Inc. Corpus Christi, TX	3	2	ND	0.11 ug/g	-	GC/ECD	Li et al. (1976). Refer to comments on ambient air (see Table 5-25). Detection limit of 0.005 t0 0.01 ug/g, dependent on sample volume.
-Linden Chlorine Linden, NJ	3	3	0.10	7.6 ug/g	-	"	Li et al. (1976).
-Olin Corporation McIntosh, AL	1	1	-	12.4 ug/g	-	"	Li et al. (1976). Only one sample.
-PPG Industries Lake Charles, LA	3	3	0.01	69 ug/g	-	"	Li et al. (1976).
-Stauffer Chemical Company Louisville, KY	3	3	0.01	200 ug/g	-	"	Li et al. (1976).
-Wolf River (Memphis, TN)	NA	NA	0.0053	0.0576 ug/g	-	NA	Jaffe et al. (1982). Mean values, for points above and below dump site, respectively. Refer to comments on surface waters (see Table 5-26).
-Nueces Estuary/Corpus Christi Bay, TX (marine environment)	8	6	BQL	7.3E-4	1.1E-4 ug/g	GC/ECD or FID	Ray et al. (1983a). Major potential sources are the numerous industrial plants, mainly petrochemical, located along the Tule Lake Channel and Corpus Christi Bay. Detection limit is 0.01 ng/g. Dry weight.

Table 5-27. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
-San Luis Pass, TX (marine environment)	6	6	5.0E-5	1.5E-3	4.9E-4 ug/g	GC	Murray et al. (1981). West Galveston Bay. Detection limit of 0.03 ng/g.
-Portland Harbor, ME (marine environment)	8	6	BQL	3.7E-4	1.4E-4 ug/g	GC/ECD or FID	Ray et al. (1983b). Major potential sources are numerous industrial plants along the harbor. Detection limit is 0.03 ng/g.
3. Soil							
a. Industrial sites:							
-Ciba-Geigy Corporation St. Gabriel, LA	4	2	ND	0.01 ug/g	-	GC/ECD	Li et al. (1976). Refer to comments on ambient air. Detection limit of 0.005 to 0.01 ug/g, dependent on sample volume.
-PPG Industries Lake Charles, LA	4	4	0.015	0.10 ug/g	-	"	Li et al. (1976).
-E. I. duPont Inc. Corpus Christi, TX	3	3	0.015	0.39 ug/g	-	"	Li et al. (1976).
-Linden Chlorine Linden, NJ	1	1	-	1.7 ug/g	-	"	Li et al. (1976). Only one sample.
-Dow Chemical Company Pittsburg, CA	3	3	0.014	2.61 ug/g	-	"	Li et al. (1976).
-Diamond Shamrock Deer Park, TX	3	3	0.06	24 ug/g	-	"	Li et al. (1976).
-Stauffer Chemical Company Louisville, KY	5	5	0.25	5,700 ug/g	-	"	Li et al. (1976).
-Vulcan Materials Company Wichita, KA	10	10	1.1 ug/g	5%	-	"	Li et al. (1976). Maximum concentrations reported as percent values.
-Olin Corporation McIntosh, AL	1	1	0.98 ug/g	13%	-	"	Li et al. (1976). Maximum concentrations reported as percent values.
-Darrow, LA (south of Baton Rouge)	NA	NA	-	-	5,000 ug/g	NA	USEPA (1975a). Results of soil samples near a landfill receiving hex wastes from a perc plant; suspected as the major source of HCB contamination of local beef cattle.

Table 5-27. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Concentration Mean	Analytical technique	Reference/comments
-Mississippi River (Baton Rouge to below New Orleans, LA)	29	NA	BQL	1.677 ug/g	-	GC/ECD	Laska et al. (1976). Dry weight basis. Levee and ditch samples. Detection limit of 0.7 ppb.
b. Urban soils							
1974 EPA Survey:							
-San Francisco, CA	164	1	ND	0.02	(0.01 ug/g	GC/ECD	Carey et al. (1985). Detection limit of 0.01 ug/g wet weight.
-Gary, IN	85	1	ND	0.59	(0.01 ug/g	"	
1975 EPA Survey:							
-Milwaukee, WI	47	2	ND	0.06	(0.01 ug/g	GC/ECD	Carey et al. (1985). Detection limit of 0.01 ug/g wet weight.
-Salt Lake City, UT	50	2	ND	0.05	(0.01 ug/g	"	
-Waterbury, CT	44	1	ND	0.30	(0.01 ug/g	"	
1976 EPA Survey:							
-Sioux City, IA	22	2	ND	0.03	(0.01 ug/g	GC/ECD	Carey et al. (1985). Detection limit of 0.01 ug/g wet weight.
-Wilmington, DE	25	1	ND	0.45	(0.01 ug/g	"	
1979 EPA Survey:							
-Washington, DC	123	1	ND	0.02	(0.01 ug/g	GC/ECD	Carey et al. (1985). Detection limit of 0.01 ug/g wet weight.
c. Agricultural soils							
-1972 EPA Survey-nationwide (37 states, 1,485 sites)	1,485	11 (6 in WA; 2 in OK; 1 in CA, MI, ID)	ND	0.44	(0.01 ug/g	GC/ECD	Carey et al. (1985). Eight detected values were from small-grain fields, one from cotton field (max value), one from soybean field, and one unknown. Three fields had HCB applied, two - PCNB, one - linuron, one - BHC/mercury, one - 2,4-D/mercury, and two unknowns. Detection limit of 0.01 ug/g dry weight.

Table 5-27. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Max	Mean	Analytical technique	Reference/comments
-1973 EPA Survey-nationwide (37 states, 1,470 sites)	1,470	1 (in CA)	ND	0.01	(0.01 ug/g	GC/ECD	Carey et al. (1985). Detected sample from a cotton field where trifluralin had been applied. Detection limit of 0.01 ug/g.
-1976 EPA Survey-nationwide (11 states, 391 samples)	391	2 (in WA)	ND	0.02	(0.01 ug/g	GC/ECD	Carey et al. (1985). Both detected values were from wheat fields. Detection limit of 0.01 ug/g dry weight.

NA - not available
ND - not detected
BQL - identified, but below quantification limits
GC - gas chromatography
ECD - electron capture detection
FID - flame ionization detection
MS - mass spectrometry
HCB - hexachlorobenzene
BHC - benzene hexachloride

Note: All reported units of concentration converted to ug/g.

Table 5-28. Summary of Biota/Food Monitoring Data for Hexachlorobenzene

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Concentration Mean	Analytical technique	Reference/comments
Aquatic biota							
1. Freshwater fish							
-Lake Ontario	NA	NA	25	100 ppb	-	NA	Niimi (1979; reported in Ray et al., 1983b). No species reported.
-Lake Ontario western basin	1	1	-	83 ppb	-	GC/ECD	Fox et al. (1983). Lake trout (S. namaycush), age 1+ years. Composite sample. Dry weight.
-Lake Ontario	NA	NA	61	127 ppb	-	"	Oliver and Nicol (1982). Lake trout, age 5+ to 6+ years.
-Lake Superior	NA	NA	-	-	13 ppb	"	Oliver and Nicol (1982). Lake trout, age 6+ years.
-Lake Superior	24	NA	-	-	5 ppb	"	Swain (1978). Lake trout. Wet weight, average for all stations.
-Mississippi River (Baton Rouge to below New Orleans, LA)	29	NA	71.8	379.8 ppb	-	"	Laska et al. (1976). Whole body tissue extracts of mosquitofish (G. affinis).
2. Freshwater invertebrates							
-Lake Ontario western basin	9	9	63	1,200	301 ppb	"	Fox et al. (1983). Oligochaete benthic worms (primarily T. tubifex). Dry weight.
-Lake Ontario western basin	8	8	90	1,600	570 ppb	"	Fox et al. (1983). Amphipods (P. hoyi, and some Gammarus spp.). Dry weight.
-Lake Ontario western basin	1	1	-	96 ppb	-	"	Fox et al. (1983). Mysid shrimp. Dry weight.
-Mississippi River (Baton Rouge to below New Orleans, LA)	29	NA	22.2	194.3 ppb	-	"	Laska et al. (1976). Crayfish, predominantly the red swamp crayfish (P. clarki), from ditches along the river.

Table 5-28. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Concentration Mean	Analytical technique	Reference/comments
3. Marine fish							
-New York Bight (offshore of Nassau County, Long Island)	NA	NA	-	-	0.45 ppb	NA	Conner (1984). An equal mixture of winter and windowpane flounder, lobster, and mussels was analyzed.
-New York Bight	NA	NA	-	-	1.1 ppb	NA	Conner (1984). Striped bass (M. saxatilis).
4. Marine invertebrates							
-San Luis Pass, TX	NA	NA	-	9.6 ppb	-	GC	Murray et al. (1981). Blue crab (C. sapidus), a commercially important marine species.
-Portland Harbor, ME	2	2	0.15	0.26 ppb	-	GC/ECD or FID	Ray et al. (1983b). Polychaete worm (N. virens).
-Portland Harbor, ME	2	2	BQL	0.61 ppb	-	"	Ray et al. (1983b). Clams (unkown species). Detection limit of 0.1 ng/g.
-Galveston Bay, TX	NA	NA	0.31	1.4 ppb	-	NA	Murray et al. (1980; reported in Ray et al., 1983b). Oysters.
Wildlife							
1. Birds	NA	NA	(200	(400 ppb	-	GC/ECD	McLane et al. (1984). Wings of woodcocks from 17 states in the eastern half of the U.S. were analyzed for HCB in 1975. Concentrations given are averages for adult and immature birds, respectively.
2. Insects	15	NA	-	(50 ppb	-	"	Beyer and Kaiser (1984). Moths from the Baltimore, MD - Washington, DC area were analyzed for HCB. Below reportable limits in all samples.

Table 5-28. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
Feed animals							
1. Beef cattle							
-Denver, CO (Lowry Bombing Range)	12	NA	-	-	10 ppb	NA	Baxter et al. (1983). Cattle grazing a municipal sewage sludge disposal site. Fat tissue, wet weight samples. No significant difference from 29 control animals. No detectable levels were found in muscle, liver, or kidney tissues.
-Darrow, LA	NA	NA	-	1,520 ppb	-	NA	USEPA (1975a). Routine analyses by the Dept. of Agriculture, far in excess of the tolerance level of 0.3 ppm in beef fat. Biopsy fat samples were obtained from 555 animals in 157 herds. 29% of the cattle tested and 34% of the herds, contained HCB at >0.5 ppm. Sources appear to be airborne emissions from industrial plants producing chlorinated hydrocarbons and waste disposal practices of these plants; particularly hex waste disposal from a local perc plant.
Food items							
1. Peanut butter	11	11	0.97	38	7.4 ppb	GC/ECD or MS	Heikes (1980). FDA routinely analyzes peanut butter for pesticide residues. PCNB is used as a soil fungicide and seed disinfectant on peanuts. HCB has been reported at significant levels in both soils treated with PCNB and in crops grown on these soils.
2. Wheat	NA	NA	ND	62 ppb	-	NA	Johns (1969), P.S.I.Ag.Ch.E.-Finland (1972); reported in Scheunert et al. (1983). Samples of wheat grown from HCB-treated seed.

Table 5-28. (continued)

Environmental compartment/ location	Number of samples	Number of detected values	Concentration Min	Concentration Max	Mean	Analytical technique	Reference/comments
3. Imported cheese	NA	NA	trace	810 ppb	-	NA	FAO-WHO (1970; reported in Booth and McDowell, 1975). On a fat basis.
4. Malt beverages	51	0	-	-	-	NA	Personal communication between J. Remmer (EPA/ OTS) and R. Dyer (BATF) on July 8, 1985. During 1983-84, the Bureau of Alcohol, Tobacco and Firearms conducted chemical analyses of 51 malt beverages (24 domestic and 27 foreign). HCB was not detected in any of the beverages at a detection limit of 1 ppb.
5. Commercial fish food	1	1	-	88 ppb	-	GC/ECD	Laska et al. (1976). Used nationwide in game fish culture. Indicates neccesity of care in toxicological studies.

NA - not available
ND - not detected
BQL - identified, but below quantification limits
GC - gas chromatography
ECD - electron capture detection
FID - flame ionization detection
MS - mass spectrometry
HCB - hexachlorobenzene
PCNB - pentachloronitrobenzene (Quinozene, Terrachlor)

Note: All reported concentration units converted to ppb.

Table 5-29. HCB Concentrations in POTW Sludges

Study	Number of POTWs analyzed	Number of POTWs detected	Percent detected	Dectection limit		Concentrations[c] (mg/kg dry weight)			
				Wet wt.[a]	Dry wt.[b]	Mean	Median	Minimum	Maximum
USEPA (1982)	44	7	16	5 - 10 ug/l	0.02 - 0.04[d] mg/kg	1.25	0.92	0.37	2.31
Jacobs et al. (1981)	237	102	43	-	0.1 mg/kg	468	18	0.188	26,200
Michigan Department of Natural Resources (1984)	27	1	4	-	0.1 mg/kg	-	-	<0.13	<1.0
NYC - Department of Environmental Protection (1983)	12	0	0	45 ug/l	0.2 mg/kg[d]	ND	ND	ND	ND
City of Galveston	3	0	0	10 ug/l	0.04 mg/kg[d]	ND	ND	ND	ND
Other studies combined (not including USEPA 1982)	279	103	37	-	-	468[e] 374[f]	-	<0.13	26,200
All studies combined	323	110	34	-	-	438[g]	-	<0.13	26,200

[a] Wet weight, usually reported in ug/l.

[b] Dry weight, usually reported in ug/kg and converted to mg/kg.

[c] Based on analysis of detected values only.

[d] Specific gravity of sludge is approximately 1, hence ug/l and ug/kg wet weight were used interchangeably (NYC - DEP 1983). Reported mean moisture content of sludge was 77 percent. This figure was used to convert wet weight to dry weight (mg/kg).

[e] Actual weighted mean.

[f] Normalized mean.

[g] Weighted by population size.

Source: COM (1984). A Comparison of Studies of Toxic Substances in POTW Sludges. Prepared by: Camp Dresser & McKee, Annandale, VA. For: USEPA, Office of Water Regulations and Standards, Criteria and Standards Division. August 1984. Contract No. 68-01-6403.

differences in data quality, it is difficult to compare specific data points within the STORET system. Another major disadvantge to some of the data in STORET is the way the qualified nondetected values are reported (i.e., by reporting HCB as detected, but below a given concentration). With concentrations reported in this manner, it is difficult to estimate the true average or mean concentrations for a given set of data.

Monitoring results for HCB in ambient streams, wells, and lakes are summarized in Tables 5-30, 5-31, and 5-32, respectively. Table 5-33 contains data from STORET on HCB levels in industrial effluents that have been reported on the relatively new NPDES Application Form 2C. Table 5-34 lists those Form 2C facilities that have reported actual measured concentrations of HCB in their industrial effluents (i.e., this table does not include qualified nondetected values). Figure 5-27 presents the locations of those facilities reporting results of HCB analysis of treated wastewater (Form 2C data).

Data on HCB levels in the environment were collected from all regions of the country. Several areas, such as the Great Lakes region and several parts of Texas, were more heavily studied than others. HCB was detected in all areas of the country. It was consistently detected in sediments and in some surface waters and soils in industrialized areas.

The nature of compiled monitoring and STORET data make inter-reference comparisons difficult. Pertinent information, such as number of samples, sampling technique, and basis for reporting (wet or dry basis) are not always provided. Reproducibility of extraction of HCB for analysis is difficult to ensure. It may, however, be assumed that the extraction techniques used were similar, though probably not identical, from study to study. Summaries for each medium are presented below.

5.6.1 Water Monitoring Data

Monitoring data for water were compiled from literature sources and STORET. Information extracted from literature is grouped into two major categories: (1) ambient water, containing data on drinking water, surface water and precipitation, and (2) wastewater with information on industrial and municipal effluents. The Great Lakes area, the focus of most studies detailed in the literature, yielded samples with the greatest HCB concentrations for ambient water. The amount of HCB monitoring data reported in STORET varies widely among regions. For

Table 5-30. STORET Ambient Stream Monitoring Data for HCB

Location	State	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Ambient Stream:								Samples collected:
Region I	CT, MA, ME, NH RI, VT	-	0	-	-	-	-	-
Region II	NJ, NY	K	69	69	5.0	0.5	0.0	1981-1984; NY only.
Region III	DE, MD, PA, VA	K	121	121	10.0	<0.001	0.0	1978-1984.
	WV	U	866	0	ND	ND	0.0	
	Total:		987	121	0.0	ND	0.0	
Region IV	AL, FL, GA, KY,	K	237	237	10.0	<0.001	0.0	1976-1984.
	MS, NC, SC, TN	U	553	0	ND	ND	0.0	
		M	5	5	-	-	-	
		N	369	369	22,000	0.06	158.291	
		N*	346*	346*	105.0*		4.186*	
	Total:		1,164	611	22,000	ND	50.396	
			1,141*	588*	105.0*		1.275*	
Region V	IL, IN, MI, MN,	K	420	420	5.0	<0.001	0.0	1975-1984; No samples
	OH, WI	U	291	0	ND	ND	ND	reported for WI.
		N	5	5	4.0	0.01	0.826	
	Total:		716	425	4.0	ND	0.006	
Region VI	AR, LA, NM, OK	K	412	412	5.0	<0.001	0.0	1973-1984.
	TX	U	95	0	ND	ND	ND	
	Total:		507	412	0.0	ND	0.0	

Table 5-30. (continued)

Location	State	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Region VII	IA, KS, MO, NE	K	315	315	360	0.001	0.0	1977-1983.
		U	102	0	ND	ND	0.0	
		N	4	4	0.19	0.03	0.0775	
	Total:		421	319	0.19	ND	<0.001	
Region VIII	CO, MT, ND, SD	K	16	16	5.0	0.5	0.0	1980-1984; No samples
	UT, WY	U	10	0	ND	ND	0.0	reported for MT, ND.
	Total:		26	16	0.0	ND	0.0	
Region IX	AZ, CA, HI, NV	K	2	2	5.0	5.0	0.0	1978-1984; No samples reported for CA, HI, NV.
Region X	AK, ID, OR, WA	K	95	95	5.0	0.5	0.0	1973-1980; No samples
		U	14	0	ND	ND	0.0	reported for AK.
	Total:		109	95	0.0	ND	0.0	
	Puerto Rico	U	1	0	ND	ND	0.0	1979.
	Washington, DC	K	2	2	5.0	0.5	0.0	1979-1980.
	Subtotal:	K	1,689	1,689	360	<0.001		
		U	1,932	0	ND	ND	0.0	
		M	5	5	-	-	-	
		N	378	378	22,000	0.06	154.534	
		N*	355*	355*	105.0*		4.092*	
	TOTAL:		4,004	2,072	22,000	ND	14.607	
			3,981*	2,049*	105.0*		0.365*	

Table 5-30. Footnotes

K - Actual value is known to be less than reported value. Assumed value of zero used in calculation of means.
U - Indicates HCB was analyzed for but not detected (ND). Nondetected values are considered as zeros in calculation of means.
N - Actual reported values (no remark code).
M - Presence of HCB verified but not quantified. These samples were not used in calculation of means.
* - Calculations after removal of the following suspicious data: 23 samples averaging 2,476.56 mg/l HCB, with a maximum reported value of 22,000 mg/l, from the following station in Jefferson County, KY:

- OHIO R EFF FRM MORRIS FOREMAN STP (77/06/09)

Table 5-31. STORET Ambient Wellwater Monitoring Data for HCB

Location	State	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Ambient wellwater:								Samples collected:
Region I	CT, MA, ME, NH RI, VT	K	4	4	0.5	0.5	0.0	1984; Samples reported for MA only.
Region II	NJ, NY	K	261	261	1,250	0.5	0.0	1979-1984.
Region III	DE, MD, PA, VA WV	K	14	14	0.5	0.5	0.0	1982-1984; Samples reported for PA only.
Region IV	AL, FL, GA, KY	K	238	238	25.0	0.5	0.0	1977-1984; No samples reported for MS.
	MS, NC, SC, TN	U	200	0	ND	ND	0.0	
		N	1	1	<0.01	<0.01	0.004	
	Total:		439	239	<0.01	ND	<<0.001	
Region V	IL, IN, MI, MN OH, WI	K	31	31	0.5	0.001	0.0	1975-1984.
Region VI	AR, LA, NM, OK TX	K	69	69	2.5	0.4	0.0	1983-1984; No samples reported for NM and OK.
Region VII	IA, KS, MO, NE	K	23	23	10.0	5.0	0.0	1978-1981; No samples reported for MO and NE.
Region VIII	CO, MT, ND, SD	K	2	2	0.5	0.005	0.0	1980-1984; Samples reported for
	UT, WY	U	1	0	ND	ND	0.0	CO and UT only.
	Total:		3	2	0.0	ND	0.0	

Table 5-31. (continued)

Location	State	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Region IX	AZ, CA, HI, NV	K	47	47	5.0	0.25	0.0	1983-1985; Samples reported for CA only.
Region X	AK, ID, OR, WA	K	7	7	5.0	0.001	0.0	1978-1980; Samples reported for OR and WA only.
		U	3	0	ND	ND	0.0	
	Total:		10	7	0.0	ND	0.0	
	Puerto Rico	K	17	17	0.5	0.5	0.0	1981-1982.
	Washington, DC	-	0	-	-	-	-	
	Subtotal:	K	713	713	1,250	0.5	0.0	
		U	204	0	ND	ND	0.0	
		N	1	1	<0.01	<0.01	0.004	
	TOTAL:		918	714	1,250	ND	<<0.001	

Means calculated assuming those samples with remark code K (actual value is known to be less than reported value) and remark code U (not detected - ND) as zero values.

N - Actual reported value (no remark code).

Table 5-32. STORET Ambient Lake Monitoring Data for HCB

Location	State	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Ambient lake:								Samples collected:
Region I	CT, MA, ME, NH RI, VT	-	0	-	-	-	-	
Region II	NJ, NY	-	0	-	-	-	-	
Region III	DE, MD, PA, VA WV	K	1	1	10.0	10.0	0.0	1982; DE only.
Region IV	AL, FL, GA, KY	K	13	13	0.5	0.001	0.0	1980-1983; Samples reported for
	MS, NC, SC, TN	U	1	0	ND	ND	0.0	FL and MS only.
	Total:		14	13	0.0	ND	0.0	
Region V	IN, IL, MI, MN	K	34	34	50.0	0.05	0.0	1975-1984.
	OH, WI	U	32	0	ND	ND	0.0	
	Total:		66	34	0.0	ND	0.0	
Region VI	AR, LA, NM; OK	K	32	32	0.25	0.001	0.0	1974-1981; Samples reported for
	TX	U	1	0	ND	ND	0.0	LA and OK only.
	Total:		33	32	0.0	ND	0.0	
Region VII	IA, KS, MO, NE	K	12	12	5.0	1.0	0.0	1978-1981; No samples reported for IA.
Region VIII	CO, MT, ND, SD UT, WY	-	0	-	-	-	-	

Table 5-32. (continued)

Location	State	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Region IX	AZ, CA, HI, NV	-	0	-	-	-	-	
Region X	AK, ID, OR, WA	K	11	11	5.0	<0.001	0.0	1978-1979.
		N	1	1	0.1	0.1	0.1	
	Total:		12	12	0.1	0.0	0.008	
	Subtotal:	K	103	103	50	<0.001	0.0	
		U	34	0	ND	ND	ND	
		N	1	1	0.1	0.1	0.1	
	TOTAL:		138	104	0.1	0.0	<0.001	

Means calculated assuming those samples with remark code K (actual value is known to be less than reported value) and remark code U (not detected - ND) as zero values.

N - Actual reported value (no remark code).

Table 5-33. STORET Industrial Effluent (Treated Outflow Pipe) Monitoring Data for HCB

Location	States	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Industrial effluent:								Sampling reported for 1983 only.
Region I	CT, MA, ME, NH, RI, VT	K	57	57	25,000	<0.001	0.0	No samples reported for CT and VT.
		U	24	0	ND	ND	0.0	
		Total:	81	57	25,000	ND	0.0	
Region II	NJ, NY	K	84	9	10.0	<0.001	0.0	
		U	69	0	ND	ND	0.0	
		N	1	1	10.0	10.0	10.0	
		Total:	154	10	10.0	ND	0.06	
Region III	DE, MD, PA, VA, WV	K	267	267	5,000	<0.001	0.0	
		U	136	0	ND	ND	0.0	
		N	3	3	11.0	0.004	5.668	
		Total:	406	270	5,000		0.04	
Region IV	AL, FL, GA, KY, MS, NC, SC, TN	K	195	195	5,000	<0.001	0.0	No samples reported for GA, MS, and NC.
		U	175	0	ND	ND	0.0	
		N	13	13	10,000	0.003	774.662	
			12*	12*	10.0*		5.883*	
		Total:	383	208	10,000	ND	26.29	
			381*	206*	10.0*		0.185*	

Table 5-33. (continued)

Location	States	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
Region V	IL, IN, MI, MN, OH, WI	K	25	25	5.0	0.005	0.0	MN only.
		U	2	0	ND	ND	0.0	
		Total:	27	25	5.0	ND	0.0	
Region VI	AR, LA, NM, OK, TX	K	304	304	5,000	<0.001	0.0	
		U	114	0	ND	ND	0.0	
		N	7	7	37.0	0.041	9.092	
		Total:	425	311	5,000	ND	0.149	
Region VII	IA, KS, MO, NE	U	14	0	ND	ND	0.0	MO only.
		Total:	14	0	ND	ND	0.0	
Region VIII	CO, MT, ND, SD VI, WY	K	9	9	5.0	0.005	0.0	SD, UT, and WY.
		U	2	0	ND	ND	0.0	
		N	2	2	<0.001	<0.001	<0.001	
		Total:	13	11	5.0	ND	<0.001	
Region IX	AZ, CA, HI, NV	K	2	2	19.25	5.0	0.0	CA and NV only.
		U	3	0	ND	ND	0.0	
		Total:	5	2	19.25	ND	0.0	
Region X	AK, ID, OR, WA	K	43	43	5.0	0.001	0.0	No samples reported for AK.
		U	38	0	ND	ND	0.0	
		N	1	1	10.0	10.0	10.0	
		Total:	82	44	10.0	ND	0.122	
	Puerto Rico	K	4	4	5.0	<0.001	0.0	
		U	9	0	ND	ND	0.0	
		Total:	13	4	5.0	ND	0.0	

Table 5-33. (continued)

Location	States	Remark code	Number of samples	Number of detections	Concentration (ug/l) Max.	Min.	Mean	Comments
	SUBTOTAL:	K	990	990	25,000	<0.001	103.036	
		U	586	0	ND	ND	0.0	
		N	27	27	10,000	<0.001	376.713	
			26*	26*	37.0*		6.586*	
	GRAND TOTAL:		1,603	1,017	25,000	ND	69.979	
			1,602*	1,016*	74.5*		0.107*	

K - Actual value is known to be less than given value. Assumed values of zero in calculation of means.

U - Indicates material was analyzed for but not detected (ND). Nondetectable values are considered zeroes in calculation of means.

N - Actual reported values, i.e., no remark code.

* - Calculations after removal of suspicious values that were used in the calculation of means.

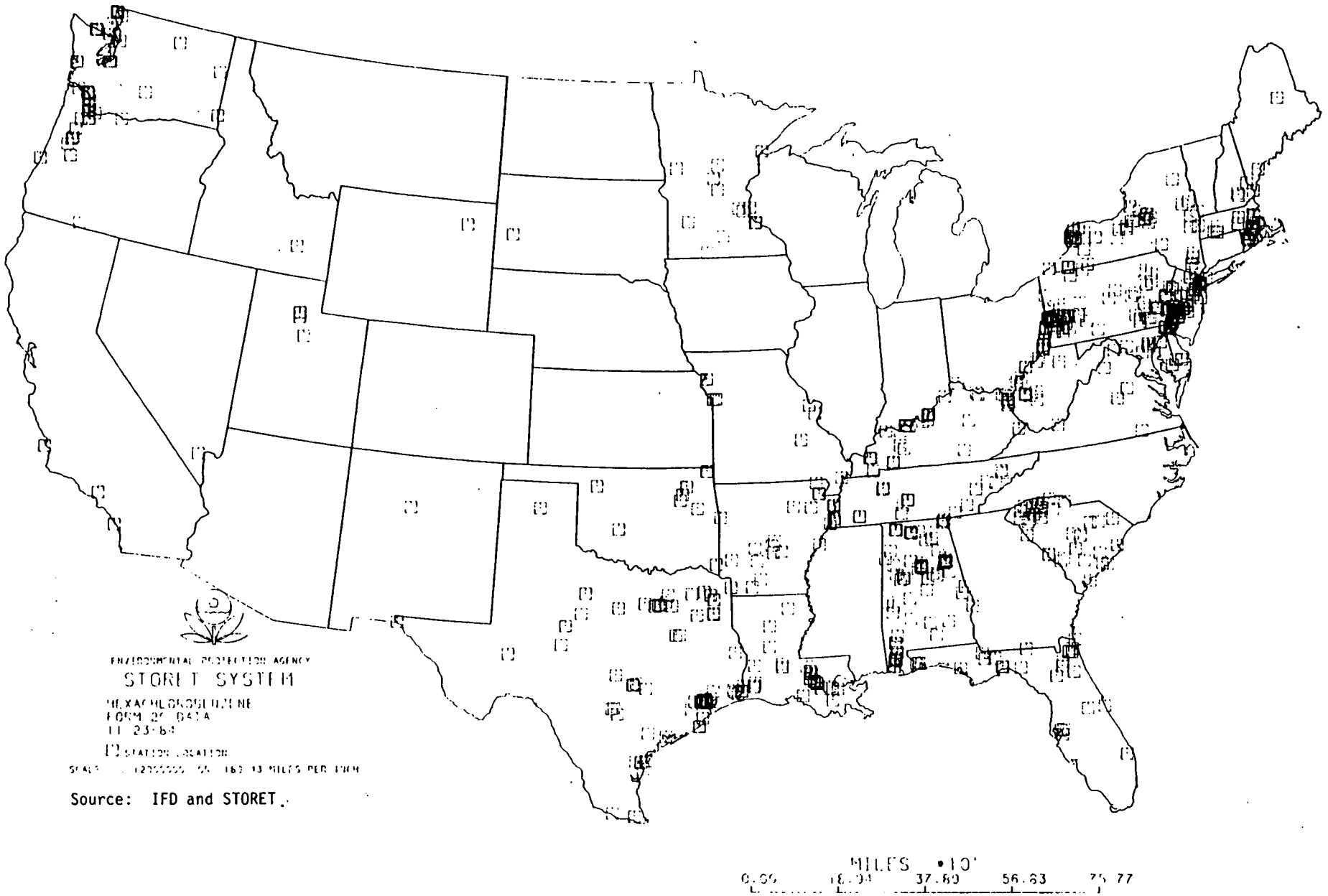
Table 5-34. Facilities Reporting Actual Detected Levels of HCB in Treated Wastewater Based on STORET Form 2C Data

Company name	Location	SIC Code[a]	Number of Samples	Concentration (ug/l) Max.	Min.	Mean
Rheen Mfg. Co.	Greenville, AL	3585	3	10	10	10
Hall Chemical	Arab, AL	2819	2	10	0.006	5.0
Dresser Ind.	Anniston, AL	3494	2	10.000	0.024	5000
Etowah Mfg. Co	Gadsen, AL	3483	1	-	-	10
Mead Corp.	Anniston, AL	3321	1	-	-	0.003
N. Birmingham Complex	Birmingham, AL	2865,3296, 3312,3321	1	-	-	0.42
Hooker Chem. Corp	Burlington, NJ	2821	1	-	-	10
Owens Corning	St.Helens, OR	2661	1	-	-	10
Babcock & Wilcox	Parks Twp., PA	3339	1	-	-	11
Zippo Mfg. Co.	Bradford City, PA	3471	1	-	-	0.003
Penelec	Warren, PA	4911	1	-	-	6
S.C. Public Service	Pinopolis, SC	4911	2	10	0.2	5.1
Quaker Oats	Memphis, TN	2865,2869	1	-	-	10
Diamond Shamrock	Deer Park, TX	2812	6	13	0.041	4.44
Brazos Elec. Coop.	Gordon, TX	4911	1	-	-	37
Caribou Four Corn.	Woods Cross, UT	2911	2	0.00009	0.00009	0.00009

[a]SIC Codes:

3585 - Manufacture of refrigeration and heating equipment
2819 - Manufacture of industrial inorganic chemicals
3494 - Manufacture of valves and pipe fittings
3483 - Manufacture of ammunition
3321 - Gray iron foundry
2865 - Manufacture of cyclic crudes and intermediates
3296 - Manufacture of mineral wool
3312 - Blast furnaces and steel mills
2821 - Manufacture of plastic materials and resins
2661 - Building paper and board mills
3339 - Manufacture of primary non-ferrous metals
3471 - Electroplating
4911 - Generation of electric power
2869 - Manufacture of industrial organic chemicals
2812 - Manufacture of alkalies and chlorine
2911 - Petroleum refining

Source: Storet/IFD, March 29, 1985.



Source: IFD and STORET.

Figure 5-27. Locations of facilities reporting results of HCB analysis of treated wastewater (form 2C data).

example, some regions have data based on a thousand or more samples while other regions have reported data for fewer than ten samples. In addition, some of the data in STORET look suspicious (e.g., a HCB ambient stream concentration of 22,000 ug/l). (See Tables 5-30 - 5-34.)

Ambient water data from the literature contain an insufficient number of drinking water studies to illustrate any regional or time trends. The maximum concentration found in drinking water was detected in 1975 at 0.006 ug/l in Region V. Ambient surface water and precipitation studies were conducted primarily in the Great Lakes area with additional sampling in Louisianna, Tennessee, and Texas. The maximum mean surface water concentration reported in any study was 8×10^{-4} ug/l in Lake Ontario at the mouth of the Niagara River, while the maximum reported mean value for precipitation was 0.1 ng/l.

The wastewater data found in the literature is divided into industrial and municipal categories. Industrial wastewater at the Vulcan Materials Company had the highest concentration, 300 ug/l of HCB; the highest value for a municipal discharge was 6.8×10^3 ug/l. No regional or temporal trends were observed.

As mentioned earlier, it is difficult to make comparisons among the data in STORET, mostly because of differences in data quality. However, it is illustrative to estimate the percent of samples that positively identify HCB. If it is assumed that HCB was not present in all samples with remark codes of "K", HCB was detected in ambient streams, wells, and lake water 10, <1, <1 percent of the time, respectively. Based on this assumption, treated industrial effluents may have contained HCB approximately 2 percent of the time. However, if it is assumed that HCB was present at less than quantifiable levels in all samples with remark codes of "K", in ambient streams, wells, and lake water, HCB was detected 52, 78, and 75 percent of the time, respectively. HCB may have been present 73 percent of the time in treated industrial effluents.

5.6.2 Air Monitoring Data

Air and occupational exposure monitoring data are provided in nine separate sources. For the years 1975 through 1979, EPA survey data were listed for sites throughout the contiguous United States. The remaining ambient air samples, the majority of which were collected near industrial facilities, were scattered throughout the country. Occupational exposure data are given for the Dow Chemical Company in Plaquemine, Louisiana, and comprise the highest concentrations included in this table. Samples gathered near industrial facilities usually show the highest concentrations of HCB in ambient air.

For the EPA survey data, mean concentrations range from less than 0.1 ng/m^3, the detection limit, to 4.4 ng/m^3 in Greenville, Mississippi. The majority of samples taken had no detectible HCB content. This was especially pronounced in 1978 when all EPA samples taken in Montana, Mississippi, and California tested negative for HCB. No regional trends are apparent in EPA or other data.

The highest concentrations of HCB in ambient air were found near industrial facilities, with maximum values detected at the Vulcan Materials Company in Wichita, Kansas. In addition to production, onsite landfill and deep-well injection of waste has occurred, resulting in a sample with a concentration of 24,000 mg/m^3. Waste disposal or storage operations characterizes facilities with four of the next five highest concentrations. This suggests that HCB release to the atmosphere can be facilitated by the storage and disposal of wastes. Samples near industrial operations were taken in 1973 or 1976, which makes a characterization of present conditions impossible. More recent studies have significantly lower concentrations; however, no conclusions may be drawn from these.

Occupational exposure data for the Dow Chemical Company in Plaquemine, Louisiana, report maximum concentrations for air and surface contact at 154,000 ng/m^3 and 124,000 ng/m^2 respectively. They are much higher than any ambient values detected but no conclusions may be formed based on only two values.

5.6.3 Sediment/Soil Monitoring Data

These data comprise information and HCB concentrations from 13 separate references found in the literature. The monitoring data are organized into three categories; suspended sediment, bottom sediment, and soil. Samples were taken from all areas of the country, but no significant regional differences were observed. Reported mean concentrations ranged from 1.1 x 10^{-4} to 5,000 ug/g. The largest concentrations were observed near industrial sites; with highest reported maximum concentration being 13 percent for the Olin facility in McIntosh, Alabama.

Suspended sediment data were obtained from samples taken in the Niagara River or in Lake Ontario at the mouth of the Niagara River. Mean concentrations, all of which were reported on a dry-weight basis, range from 0.005 to 0.124 ug/g. The highest concentrations were found near the Lower Niagara River while the lowest concentrations were from the upper reaches. This suggests that the suspended sediment load of the Niagara becomes increasingly rich with HCB as it moves downstream.

Bottom sediment was collected primarily in the Great Lakes area with samples also taken in southern, midwestern, eastern, and northeastern regions. Of the sites in the Great Lakes region, the highest mean concentration, 55 ug/g, was detected in the lower Niagara. This supports the evidence suggested by suspended sediment data, that HCB concentration increases downstream in the Niagara River. The maximum concentration found in any bottom sediment was 200 ug/g near the Stauffer Chemical Company in Louisville, Kentucky. Concentrations reported cannot be specifically compared since testing procedures may have included surficial or core samples.

Soil samples were taken at industrial, urban, and agricultural sites throughout the country. Two exceptionally high concentrations were noted at the Vulcan Materials Company in Wichita, Kansas, and at the Olin Corporation in McIntosh, Alabama. These values, expressed as 5 and 13 percent respectively (approximately 50,000 and 130,000 ug/g) were roughly one and two orders of magnitude higher than others found for soils. A relatively low 6.7 percent of urban and 0.42 percent of samples gathered at agricultural sites contained detectable levels of HCB. All mean values reported for urban and agricultural sites were below the detectable limit of 0.01 ug/g. Urban and agricultural samples were taken by EPA in national surveys conducted from 1972 to 1979. From the soil data, it may be concluded that industrial facilities are a primary source for HCB contamination of this medium.

5.6.4 Biota and Food Monitoring Data

A total of 16 sources were found in the literature listing HCB concentrations in either aquatic biota, wildlife, feed animals, or food items. The Great Lakes area was the focus of freshwater studies with additional studies being done in the South, Northeast, Southwest, and West. The variety of organisms tested makes determination of regional trends difficult.

The mean concentrations given range from 0.45 ppb for marine fish in the New York Bight to 570 ppb for freshwater invertebrates in the western basin of Lake Ontario. The western basin is also the site of the maximum concentration; a measurement of 1,600 ppb for freshwater invertebrates. Beef cattle data include a maximum concentration of 1,520 ppb for cattle in Darrow Louisanna, a value three times greater in magnitude than the USDA enforcement level of 0.5 ppm of HCB in beef fat. Industrial sources appear to be the common denominator for the high level in these two samples. The Great Lakes area is heavily industrialized and air emissions from plants producing chlorinated hydrocarbons are thought to be the source for the Darrow, Louisiana, cattle.

5.7 References

Atlas E, Giam CS. 1981. Global transport of organic pollutants: ambient concentrations in the remote marine atmosphere. Science 211(4478):163-165.

Barquet A, Carmen M, Pfaffenberger CD. 1981. Determination of organochlorine pesticides and metabolites in drinking water, human blood serum, and adipose tissue. J. Toxicology and Environ. Health 7:469-479.

Baxter JC, Aquilar M, Brown K. 1983. Heavy metals and persistent organics at a sewage sludge disposal site. J. Environ. Qual. 12(3):311-315.

Beyer WN, Kaiser TE. 1984. Organochlorine pesticide residues in moths from the Baltimore, MD - Washington, DC area. Environ. Monit. and Assess. 4:129-137.

Billings WN, Bidleman TF. 1983. High volume collection of chlorinated hydrocarbons in urban air using three solid adsorbents. Atmos. Env. 17(2):383-391.

Billings WN, Bidleman TF. 1980. Field comparison of polyurethane foam and tenax-GC resin for high-volume air sampling of chlorinated hydrocarbons. Envir. Sci. Tech. 14(6):679-683.

Boland PA. 1981. National screening program for organics in drinking water. Washington, DC: U.S. Environmental Protection Agency, Office of Drinking Water. EPA Contract No. 68-01-4666.

Booth NH, and McDowell JR. 1975. Toxicity of hexachlorobenzene and residues in edible animal tissues. J. Am. Vet. Med. Assoc. 166(6):591-595.

Brooks GW, Hunt GE. 1984. Source assessment for hexachlorobenzene. Research Triangle Park, NC: Pollution Asessment Branch, U.S. Environmental Protection Agency. EPA Contract No. 68-02-3818.

Bunck CM. 1985. Residue levels of hexachlorobenzene (HCB) in wildlife from the United States. Unpublished report. Laurel, MD: U.S. Dept. of the Interior, Fish and Wildlife Service.

Cain BW, Bunck CM. 1983. Residues of organochlorine compounds in starlings (Sturnus vulgaris), 1979. Environ. Monit. and Assess. 3:161-172.

Cain BW. 1981. Nationwide residues of organochlorine compounds in wings of adult mallards and black ducks, 1979-80. Pest. Monit. J. 15(3):128-134.

Carey AE, Dixon TE, Yang HSC. 1985. Environmental exposure to hexachlorobenzene in the United States. Washington, DC: U.S. Environmental Protection Agency, Ofice of Pestcides and Toxic Substances.

Conner MS. 1984. Comparison of the carcinogenic risks from fish vs. groundwater contamination by organic compounds. Environ. Sci. and Tech. 18(8):628-631.

Currier MF, McClimans CD, Barna-Lloyd G. 1980. Hexachlorobenzene blood levels and the health status of men employed in the manufacture of chlorinated solvents. J. Toxicology and Environ. Health 6:367-377.

Duggan RE, Carveliusser PE, Duggan MB, Memahom BM, Martin RJ. 1983 Pesticide residue levels in foods in the United States from July 1, 1969 to June 30, 1976. Washington, DC: U.S. Food and Drug Administration, Arlington, VA; Association of Ethical Analytical Chemicals.

Eisenreich SJ, Hollod GJ, Johnson TC. 1980. Assessment of airborne organic contaminants in the Great Lakes ecosystem, Science Advisory Board, Windsor, Ontario. (as reported in Eisenreich et al. 1981.)

Eisenreich SJ, Looney BB, Thornton JD. 1981. Airborne organic containmants in the Great Lakes ecosystem. Environ. Sci. and Tech. 15(1):30-38.

Elder VA, Proctor BL, Hites RA. 1981. Organic compounds found near dump sites in Niagara Falls, New York. Environ. Sci. and Tech. 15(10):1237-1243.

FAO-WHO. 1970. Evaluation of some pesicides in food: hexachlorobenzene WHO/Food additives monograph. FAO/PL/1969/M/17/1. (as reported in Booth and McDowell 1975.)

FDA. 1971. The Food and Drug Administration's pesticide analytical manual. Washington, DC: U.S. Department of Health, Education, and Welfare, Food and Drug Administration.

Finland. 1972. Investigation on pesticide residues in 1971. Publications of the State Institute of Agricultural Chemistry, Helsinki, Finland. (as reported in Scheunert et al. 1983.)

Fox ME, Carey JH, Oliver BG. 1983. Compartmental distribution of organochlorine contaminants in the Niagara River and the western basin of Lake Ontario. J Great Lakes Res. 9(2):287-294.

Gartrell MJ, Craun JC, Podrebarac DS, Gunderson EL. 1985a. Pesticides, selected elements, and other chemicals in infant and toddler total diet samples, October 1979-September 1980. J. Assoc. Off. Anal. Chem. 68(6):1163-1183.

Gartrell MJ, Craun JC, Podrebarac DS, Gunderson EL. 1985b. Pesticides, selected elements, and other chemicals in adult total diet samples, October 1979-September 1980. J. Assoc. Off. Anal. Chem. 68(6):1184-1197.

Gartrell MJ, Craun JC, Podrebarac DS, Gunderson EL. 1986a. Pesticides, selected elements, and other chemicals in infant and toddler total diet samples, October 1980 - March 1982. J. Assoc. Off. Anal. Chem. 69(1):123-145.

Gartrell MJ, Craun JC, Podrebarac DS, Gunderson EL. 1986b. Pesticides, selected elements, and other chemicals in adult total diet samples, October 1980 - March 1982. J. Assoc. Off Anal. Chem. 69(1):146-159.

Heikes DL. 1980. Residues of pentachloronitrobenzene and related compounds in peanut butter. Bull. Environ. Contam. Toxicol. 24:338-343.

JRB Assoc. 1984. Occurrance of miscellaneous synthetic organic chemicals in drinking water, food, and air. Washington, DC: Office of Drinking Water, U.S. Environmental Protection Agency. EPA Contract No. 68-01-9388.

Jaffe PR, Parker FL, Wilson DJ. 1982. Distribution of toxic substances in rivers. J. Environ. Eng. 108 (EE4):639-649.

Johns TH. 1969. Translation of HCB in wheat. Report to Australian Pesticides Sub-Committee from N.S.W. Department of Agriculture. (as reported in Scheunert et al. 1983.)

Johnson, RD, Manske DD, Podrebarac DS. 1981. Pesticide, metal, and other chemical residues in adult total diet study samples. (XII). August 1975-July 1976. Pest. Monit. J. 15(1):54-69.

Johnson RD, Manske DD, New DH, Podrebarac DS. 1984. Pesticide, metal, and other chemical residues in adult total diet samples. (XIII). August 1976-September 1977. J. Assoc. Off. Anal. Chem. 67(1):154-166.

Johnson RD, Manske DD. 1976. Pesticide residues in total diet samples (IX). Pest. Monit. J. 9(4): 157-169.

Johnson RD, Manske DD. 1977. Pesticide and other chemical residues in total diet samples (XI). Pest. Monit. J. 11(3):116-131.

Kauss PB. 1983. Studies of trace contaminants, nutrients, and bacteria levels in the Niagara River. J. Great Lakes Res. 9(2):249-273.

Kuntz KW, Warry ND. 1983. Chlorinated organic contaminants in water and suspended sediments of the lower Niagara River. J. Great Lakes Res. 9(2):241-248.

Laska AL, Bartell CK, Laseter JL. 1976. Distribution of hexachlorobenzene and hexachlorobutadiene in water, soil, and selected acquatic organisms along the lower Mississippi River, Louisiana. Bull. of Environ. Contam. and Toxicol. 15(5):535-542.

Li RT, Spigarelli JL, Going JE. 1976. Sampling and analysis of selected toxic substances, task 1A - hexachlorobenzene. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. EPA-560/6-76-001 (PB 253-794).

Mack GA, Mohadjer L. 1985. Baseline estimates and time trends for B-BHC, HCB and PCBs in human adipose tissue 1970-1983. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. EPA Contract No. 68-01-6721.

Manske DD, Johnson RD. 1977. Pesticide and other chemical residues in total diet samples (X). Pest. Monit. J. 10(4): 134-148.

Martin WE. 1969. Organochlorine insecticide residues in starlings. Pest. Monit. J. 3:102-114.

McLane MAR, Hughes DL, Heinz GH. 1984. Changes in levels of organochlorines in woodcock wings from 1971-1975. Environ. Monit. and Assess. 4:105-111.

Murray HE, Ray LE, Giam CS. 1981. Analysis of marine sediment, water, and biota for selected organic pollutants. Chemosphere 10(11/12):1327-1334.

Murray HE et al. 1980. Bull. Environ. Contam. Toxcol. 25:663-667. (as reported in Ray et al. 1983b.)

Nickerson PR, Barbehenn KR. 1975. Organochlorine residues in starlings, 1972. Pest. Monit. J. 8(4): 247-254.

Niimi AJ. 1979. Bull. Environ. Contam. Toxicol. 23:20-24. (as reported in Ray et al. 1983b.)

Oliver BG, Nicol KD. 1982. Chlorobenzenes in sediments, water, and selected fish from Lakes Superior, Huron, Erie, and Ontario. Environ. Sci. and Tech. 16:532-536.

Podrebarac DS. 1984. Pesticide, metal, and other chemical residues in adult total diet samples. (XIV). October 1977-September 1978. J. Assoc. Off. Anal. Chem. 67(1):176-185.

Prouty RM, Bunck CM. Organochlorine residues in adult mallard and black duck wings, 1981-1982. (in press).

Ray RE, Murray HE, Giam CS. 1983a. Analysis of water and sediment from the Nueces Estuary/Corpus Christi Bay (Texas) for selected organic pollutants. Chemosphere 12(7/8):1039-1045.

Ray RE, Murray HE, Giam CS. 1983b. Organic pollutants in marine samples from Portland, Maine. Chemosphere 12(7/8):1031-1038.

Robinson PE, Leczynski BA, Kutz FW, Remmers JC, Carra JS. 1985. An evaluation of hexachlorobenzene body burden levels in the general United States population. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances.

Scheunert I, Marra C, Viswanathan R, Klein W, Korte F. 1983. Fate of hexachlorobenzene-^{14}C in wheat plants and soil under outdoor conditions. Chemosphere 12(7/8):843-858.

Schmitt CJ, Ludke JL, Walsh DF, 1981. Organochlorine residues in fish: National pesticide monitoring program, 1970-74. Pest. Monit. J. 14(4):136-206.

Schmitt CJ, Ribick MA, Ludke JL, May TW. 1983. National pesticide monitoring program: organochlorine residues in freshwater fish, 1976-79. Washington, DC: U.S. Dept. of the Interior, Fish and Wildlife Service Resource Publication 152.

Schmitt CJ, Zajicek JL, Ribick MA. 1985. National pesticide monitoring program: residues of organochlorine chemicals in freshwater fish, 1980-81. Arch. Environ. Contam. Toxicol. 14:225-260.

Staples CA, Werner AF, Hoogheem TJ. 1985. Assessment or priority pollutant concentrations in the United States using STORET database. Environ. Toxicol. and Chem. 4:131-142.

Swain WR. 1978. Chlorinated organic residues in fish, water, and precipitation from the vicinity of Isle Royale, Lake Superior. J Great Lakes Res. 4(3-4):398-407.

USDA. 1981. Livestock slaughter - annual summary 1980. Washington, DC: Economics and Statistics Service, Crop Reporting Board, U.S. Department of Agriculture.

USDA. 1982. Agricultural Statistics (Table 481), 1982.

USEPA. 1975a. Survey of industrial processing data. Task I - hexachlorobenzene and hexachlorobutadiene pollution from chlorocarbon processes. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. PB 243-641.

USEPA. 1975b. Preliminary assessment of suspected carcinogens in drinking water, report to Congress. Washington, DC: U.S. Environmental Protection Agency. PB 250961.

USEPA. 1976. Environmental contamination from hexachlorobenzene. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency. PB 251-874.

White DH, Heath RG. 1976. Nationwide residues of organochlorines in wings of adult mallards and black ducks, 1972-73. Pest. Monit. J. 9(4):176-185.

White DH. 1976. Nationwide residues of organochlorines in starlings, 1974. Pest. Monit. J. 10(1): 10-17.

White DH. 1979a. Nationwide residues of organochlorine compounds in starlings (Sturnus vulgaris), 1976. Pest. Monit. J. 12(4): 193-197.

White DH. 1979b. Nationwide residues of organochlorine compounds in wings of adult mallards and black ducks, 1976-77. Pest. Monit. J. 13(1):12-16.

Young DR and Heesen TC. 1976. Inputs of chlorinated benzenes. Coastal Water Research Project/Sources of Pollution. Annual Report. Southern California Research Project. 31-37.

6. MODELING DATA

This section contains the results of the modeling work. Two sets of modeling data were developed: (1) estimated HCB concentrations in air downstream of seven industrial incinerators and (2) estimated HCB concentrations in air and ground water resulting from landfill releases.

6.1 Air Concentrations Downstream of Industrial Incinerators

Releases from industrial incinerators were modeled for seven sites using the Industrial Source Complex Long Term (ISCLT) model to assess their impact on ground-level concentrations of HCB in air. The seven facilities modeled along with their locations and associated estimated release data are presented in Table 6-1.*

The latitude/longitude values in Table 6-1 were used to determine what meteorological data were appropriate for modeling these particular sources. The OTS Graphical Exposure Modeling System (GEMS) Atmospheric Modeling Subsystem (GAMS) was used to make that determination. In the case of Wichita, Kansas (Vulcan), Oklahoma City, Oklahoma, (240 km away from Wichita) was used because it was the only available similar data set that could be used in the ISCLT model. Although Wichita data could not be used directly, they could be compared with the Oklahoma City data, and that comparison showed no major differences in meteorological conditions between the two sites. Oklahoma City data looked as if they would produce more conservative results because of somewhat higher freqencies

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*EPA's Office of Air Quality Planning and Standards (OAQPS) previously estimated HCB air levels downwind of these seven facilities using the CDM model and HCB release estimates (assuming 99.99 percent DRE) provided in Brooks and Hunt (1984) (Zaragoza 1984). The OAQPS modeling work differs from the modeling discussed here primarily in the choice of models used and several input parameters dealing with HCB waste generation rates. Brooks and Hunt (1984) based their HCB generation rates on 1984 plant capacity data and information from the open literature concerning chlorinated solvent waste generation rates and HCB concentrations in these wastes. The Versar modeling used 1985 plant capacity data adjusted with U.S. International Trade Commission data (USITC 1985) to provide estimates of actual chemical production. Versar used estimates provided by EPA's Office of Solid Waste (OSW 1985) for chlorinated solvent waste generation rates and HCB concentrations in these wastes. These OSW estimates were made based on open literature information and confidential information (OSW 1985). The OAQPS modeling results differ from the Versar results for 99.99 percent DRE typically by a factor of six or less.

Table 6-1. Location and Release Data for the Seven Modeled Industrial Incinerators

Company	Plant location	Latitude/Longitude[a]	Chemical	Production capacity (10^6 lbs)[b]	Estimated HCB incinerated[c] (kkg/year)	Estimated total HCB release[d] (kg/yr)
Diamond Shamrock Corp.	Deer Park, TX	294335/950540	Perchloroethylene	165	584	58.4
Dow Chemical, U.S.A.	Freeport, TX	285857/952310	Trichloroethylene	120	49	4.9
Dow Chemical, U.S.A.	Plaquemine, LA	301700/911416	Carbon Tetrachloride	125	245	67.0
			Perchloroethylene	120	425	
Dow Chemical, U.S.A.	Pittsburg, CA	380142/1215117	Carbon Tetrachloride	80	157	33.4
			Perchloroethylene	50	177	
PPG Industries, Inc.	Lakes Charles, LA	301328/931657	Perchloroethylene	200	708	79.0
			Trichloroethylene	200	82	
Vulcan Materials Co.	Geismar, LA	301115/905902	Perchloroethylene	150	531	70.7
			Carbon Tetrachloride	90	176	
Vulcan Materials Co.	Wichita, KS	373451/972521	Perchloroethylene	50	177	29.5
			Carbon Tetrachloride	60	118	

[a]Source: Brooks and Hunt (1984); based on data in NEDS (National Emissions Data System), a data base maintained by the Monitoring and Data Analysis Division of EPA's Office of Air Quality Planning and Standards.

[b]Source: SRI 1985 Directory of Chemical Producers (estimates as of January 1, 1986).

[c]Assumes 0.04 kg of waste produced per kg of product (OSW 1985). Assumes the following HCB content of wastes (OSW 1985): perchloroethylene-25 percent; carbon tetrachloride 15 percent; trichloroethylene-5 percent. Assumes the following production/capacity ratios: perchloroethylene-78 percent; carbon tetrachloride-72 percent; trichloroethylene-45 percent. The production/capacity ratios are based on capacity data from SRI 1985 Directory of Chemical Producers and production data from Table 3-9 (Section 3.2.2 of this report). In all cases, it was assumed that the entire quantity of HCB was burned in only one incinerator.

[d]The estimated release is based on a destruction and removal efficiency of 99.99.

of certain wind directions and lower wind speeds; this should be considered during review of the results for the Vulcan plant in Wichita.

None of the specific incinerator stack parameters for the seven modeled facilities was known; therefore, it was necessary to assume stack parameters. To account for the potential variations in the incinerator design and conditions, two sets of stack parameters were modeled for all seven sites:

	Model Incinerator A	Model Incinerator B
Stack height	15.2 meters	27.4 meters
Stack diameter	2.4 meters	2.1 meters
Exit gas velocity	7.1 meters/second	6.4 meters/second
Exit gas temperature	346°K	366°K
Operating characteristics	300 days/year 24 hours/day	300 days/year 24 hours/day

The stack parameters for Model Incinerator A were obtained directly from Brooks and Hunt (1984)*. These parameters are based on actual data from two hazardous waste incinerators that are known to have burned HCB wastes. The stack parameters for Model Incinerator B were taken directly from Holton et al. (1984)**, and they are based on a review of existing incinerators and engineering judgment.

In addition to modeling two sets of stack parameters, it was assumed that the DRE for the incinerators may fluctuate by an order of magnitude from the best estimate of 99.99 percent. The estimated maximum annual average concentrations for all three DREs are given in Table 6-2. The ISCLT model estimated concentrations at a distance ranging from 200 to 50,000 meters away from the source; the maximum concentrations generally occurred between 800 and 1,000 meters from the source.

Note that releases from Model Incinerator A consistently resulted in higher downstream concentrations than releases from Model Incinerator B. In addition, it was found that the highest emitters did not necessarily produce the highest downwind concentrations. For example, the Dow Chemical plant in Pittsburgh, California, (ranked fifth in estimated emissions) produced the highest estimated downwind concentrations mostly because of the meteorological conditions in that region.

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*A source assessment for HCB prepared for EPA's Office of Air Quality Planning and Standards.

**An assessment of emissions from incineration of pesticide-related wastes; prepared for the Incineration Review Branch of EPA's Office of Research and Development.

Table 6-2. Predicted Maximum Annual Concentrations (ug/m^3) Downstream of Seven Industrial Incinerators

		Worst case[a]		Best estimate[b]		Best case[c]	
Company	Plant Location	Incinerator A	Incinerator B	Incinerator A	Incinerator B	Incinerator A	Incinerator B
Diamond Shamrock Corp.	Deer Park, TX	1.0×10^{-2}	6.5×10^{-3}	1.0×10^{-3}	6.5×10^{-4}	1.0×10^{-4}	6.5×10^{-5}
Dow Chemical, U.S.A.	Freeport, TX	9.1×10^{-4}	5.9×10^{-4}	9.1×10^{-5}	5.9×10^{-5}	9.1×10^{-6}	5.9×10^{-6}
Dow Chemical, U.S.A.	Plaquemine, LA	5.4×10^{-3}	3.7×10^{-3}	5.4×10^{-4}	3.7×10^{-4}	5.4×10^{-5}	3.7×10^{-5}
Dow Chemical, U.S.A.	Pittsburg, CA	1.3×10^{-2}	8.5×10^{-3}	1.3×10^{-3}	8.5×10^{-4}	1.3×10^{-4}	8.5×10^{-5}
PPG Industries, Inc.	Lake Charles, LA	1.1×10^{-2}	7.4×10^{-3}	1.1×10^{-3}	7.4×10^{-4}	1.1×10^{-4}	7.4×10^{-5}
Vulcan Materials Co.	Geismar, LA	5.7×10^{-3}	3.9×10^{-3}	5.7×10^{-4}	3.9×10^{-4}	5.7×10^{-5}	3.9×10^{-5}
Vulcan Materials Co.	Wichita, KS	1.1×10^{-2}	7.1×10^{-3}	1.1×10^{-3}	7.1×10^{-4}	1.1×10^{-4}	7.1×10^{-5}

[a]Assumes a 99.9 percent DRE.
[b]Assumes a 99.99 percent DRE.
[c]Assumes a 99.999 percent DRE.

Source: Hlinka (1986).

6.2 Air and Ground-Water Concentrations Resulting from HCB Releases from Landfills

The atmospheric exposure and ground-water concentrations resulting from hexachlorobenzene in landfills were estimated for several scenarios using computer simulation models. The scenarios included two sites (Tacoma, Wahington, and Memphis, Tennessee), two landfill sizes (1/2 acre and 1 acre), and four clay cap thicknesses for the atmospheric exposure simulation (0, 6, 12, and 24 inches). All simulations were performed for a 20-year time period, starting at the time loading to the landfill began. Details on the exact assumptions and models used in this analysis are contained in GSC (1986). For convenience, GSC (1986) has been included in Appendix F of this report. A brief summary of the results is presented in this section.

6.2.1 Air Concentrations

The SESOIL model was used to estimate HCB volatilization rates from a landfill to the atmosphere. The Industrial Source Complex Long-Term model was then used to estimate the annual average ground-level atmospheric concentrations near the landfill. The original estimates (GSC 1986) were based on the assumption that both sites receive a total of 12,100 metric tons of industrial sludge for 10 years (i.e., 1,210 tons/yr for years 1 to 10). The sludge was assumed to contain HCB at a concentration of 100 ppm at the Memphis site and 10 ppm at the Tacoma site. However, since HCB loadings from the sludge are linear with respect to air concentrations (personal communication between Clay Carpenter of Versar Inc. and Scott Rheingraver of GSC on Table 6-1 April 18, 1986), it was assumed that HCB was found at higher concentrations in the waste in order to obtain more worst case scenarios. The concentrations presented in this section are based on the assumption that the sludge at both sites consists of HCB in concentrations of 100 and 1,000 ppm. The resulting concentrations are given in Table 6-3. Maximum concentrations were found at the Memphis site for the 1 acre landfill that has a zero inch clay cap.

6.2.2 Ground-Water Concentrations

The SESOIL model was used to simulate the vertical transport of HCB from the landfill through the unsaturated zones to the ground-water surface, and the AT123D model was used to simulate HCB concentrations in ground water. As previously stated, all model runs were performed over a 20-year simulation period with sludge disposal assumed to begin at year 1 and end at year 10. Maximum ground-water concentrations of HCB were reached at year 20. The system, however, had still not reached steady-state by year 20, and higher concentrations would be expected for longer simulation periods. It was estimated that steady-state would be

Table 6-3. Estimated Annual Average Intra-Ring Concentrations (ug/m^3) Based on HCB Volatilization from a Landfill

	Memphis, Tennessee				Tacoma, Washington			
Clay cap (inches)	1/2-Acre landfill 100 ppm HCB in sludge	1/2-Acre landfill 1,000 ppm HCB in sludge	1-Acre landfill 100 ppm HCB in sludge	1-Acre landfill 1,000 ppm HCB in sludge	1/2-Acre landfill 100 ppm HCB in sludge	1/2-Acre landfill 1,000 ppm HCB in sludge	1-Acre landfill 100 ppm HCB in sludge	1-Acre landfill 1,000 ppm HCB in sludge
8	1.01×10^{-6}	1.01×10^{-5}	1.74×10^{-6}	1.74×10^{-5}	1.0×10^{-6}	1.00×10^{-5}	1.78×10^{-6}	1.78×10^{-5}
6	1.11×10^{-7}	1.11×10^{-6}	1.92×10^{-7}	1.92×10^{-6}	3.58×10^{-7}	3.58×10^{-6}	6.34×10^{-7}	6.34×10^{-6}
12	1.06×10^{-7}	1.06×10^{-6}	1.84×10^{-7}	1.84×10^{-6}	3.42×10^{-7}	3.42×10^{-6}	6.05×10^{-7}	6.05×10^{-6}
24	9.72×10^{-8}	9.72×10^{-7}	1.68×10^{-7}	1.68×10^{-6}	3.12×10^{-7}	3.12×10^{-6}	5.52×10^{-7}	5.52×10^{-6}

Source: Derived from GSC (1986).

reached in approximately 100 years, although it may take up to 500 years (personal communication between Clay Carpenter of Versar Inc. and Jim Pilot of GSC on April 22, 1986).

Like volatilization from landfills, ground-water concentrations have a linear relationship to loadings from the landfill (personal communication between Clay Carpenter of Versar Inc. and Jim Pilot of GSC on April 22, 1986). To simulate more worst case scenarios, it was assumed that the sludge in both landfills contains HCB at concentrations of 100 and 1,000 ppm. All other assumptions are identical to those contained in GSC (1986).

The resulting concentrations of HCB in ground-water are presented in Table 6-4. The highest concentrations are found at the Tacoma Site, although the contaminated plume had not spread far from the center of the landfill by year 20.

Table 6-4. HCB Concentrations in Ground Water (ug/l) at the Water Table Surface along Plume Centerline[a]

Horizontal distance from landfill (meters)	Memphis, Tennessee				Tacoma, Washington			
	1/2-Acre landfill 100 ppm HCB in sludge	1/2-Acre landfill 1,000 ppm HCB in sludge	1-Acre landfill 100 ppm HCB in sludge	1-Acre landfill 1,000 ppm HCB in sludge	1/2-Acre landfill 100 ppm HCB in sludge	1/2-Acre landfill 1,000 ppm HCB in sludge	1-Acre landfill 100 ppm HCB in sludge	1-Acre landfill 1,000 ppm HCB in sludge
8	1.1×10^{-7}	1.1×10^{-6}	1.1×10^{-7}	1.1×10^{-6}	2.7×10^{-5}	2.7×10^{-4}	2.7×10^{-5}	2.7×10^{-4}
20	7.7×10^{-8}	7.7×10^{-7}	1.0×10^{-7}	1.0×10^{-6}	2.6×10^{-5}	2.6×10^{-9}	2.7×10^{-5}	2.7×10^{-4}
40	6.0×10^{-9}	6.0×10^{-8}	2.0×10^{-8}	2.0×10^{-7}	0	0	5.1×10^{-10}	5.1×10^{-9}
60	4.3×10^{-10}	4.3×10^{-9}	1.5×10^{-9}	1.5×10^{-8}	0	0	0	0
80	2.2×10^{-11}	2.2×10^{-10}	9.5×10^{-11}	9.5×10^{-11}	0	0	0	0
100	7.3×10^{-13}	7.3×10^{-12}	3.9×10^{-12}	3.9×10^{-11}	0	0	0	0
120	1.5×10^{-14}	1.5×10^{-13}	1.0×10^{-13}	1.0×10^{-12}	0	0	0	0
140	1.8×10^{-15}	1.8×10^{-14}	1.6×10^{-15}	1.6×10^{-14}	0	0	0	0
160	4.4×10^{-19}	4.4×10^{-18}	1.2×10^{-17}	1.2×10^{-16}	0	0	0	0
180	0	0	0	0	0	0	0	0

[a]These are the maximum concentrations, which were reached in year 20 of the analysis. Note that steady-state had not been attained by year 20, and higher concentrations in ground water would be expected for longer simulation periods.

Source: GSC (1986).

6.3 References

Brooks GW, Hunt GE. 1984. Source assessment for hexachlorobenzene. Research Triangle Park, NC: U.S. Environmental Protection Agency. EPA Contract No. 68-02-3818.

GSC. 1986. Modeling inhalation exposure and groundwater contamination of hexachlorobenzene from landfills. Draft report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Contract No. 68-02-3968.

Holton GA, Travis CC, Etnier EL et al. 1984. Multiple-pathways screening-level assessment of a hazardous waste incineration facility. Oak Ridge, TN: Oak Ridge National Laboratory. Report No. ORNL/TM-8652.

Hlinka, D. 1986. Modeling of two incinerators emitting hexachlorobenzene at seven sites. Memorandum to Clay Carpenter (Versar Inc.) on August 8, 1986.

Industrial Economics, Inc. 1985. Comparisons of risks from land-based and ocean-based incineration. Draft report. Washington, DC: Office of Policy Analysis, U.S. Environmental Protection Agency.

PEI. 1985. Sources of hexachlorobenzene. Memorandum to Paul Quillen (Office of Toxic Substances, U.S. Environmental Protection Agency) on December 31, 1985.

Zaragoza LJ. 1984. Hexachlorobenzene exposure and risk assessment. Memorandum to the Files. Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

7. EXPOSURE SCENARIOS

This section presents several exposure scenarios that were developed to estimate human exposure to HCB. Scenarios in this section are based on modeling estimates of HCB levels in the environment and on HCB monitoring data. Besides the modeling results from Section 6, other modeling data, which were generated by the USEPA, were used to develop scenarios for the ingestion of pesticide-contaminated food. These models were based on the tolerances of pesticides allowed in food and not on specific sources of HCB contamination. All monitoring data used in the exposure scenarios were extracted directly from Section 5.

Five sets of scenarios are presented in this section, with a separate subsection for each. These are related to assessment of exposure to the following: (1) ambient air, (2) drinking water, (3) food (based on FDA market basket studies), (4) fish, and (5) pesticide-laden food (based on the tolerances to four pesticides that are known to contain HCB). Table 7-1 summarizes the results of the scenarios for inhalation exposure, drinking water exposure, and exposure through food.

In addition to the exposure scenarios, a separate subsection is presented on the pharmacokinetic modeling of the National Human Adipose Tissue Survey (NHATS) data. This subsection discusses the linkage between steady-state exposures of HCB and levels found in human adipose tissues.

7.1 Inhalation Exposure

Inhalation exposure was estimated based on three sets of data: (1) ambient air monitoring data, (2) modeling data of ambient air concentrations near industrial incinerators that may be releasing HCB, and (3) modeling data of ambient air concentrations near a hypothetical landfill that contains HCB. In all cases, the following equation was used to calculate annual exposure:

$$EXP = (IR)(C)(D)(F)$$

where

EXP = annual inhalation exposure
IR = inhalation rate
C = ambient concentration
D = duration of exposure
F = frequency of exposure.

Furthermore, the weighted average inhalation rate for all ages, sexes, and activities is assumed to be 0.79 m^3/hr (Freed et al. 1983). Duration was assumed to be 24 hrs/day, and frequency was assumed to be 365 days/yr.

Table 7-1. Summary of the Exposure Scenarios for HCB

Exposure route	Exposure range (ug/yr)	Best estimate (ug/yr)	Best estimate (ug/kg/day)
Inhalation			
Monitoring data[a]	<0.69 - 30.4	3.5[d]	1.4×10^{-4}
Incinerator modeling data	0.04 - 90.0	0.4 - 9.0[e]	1.6×10^{-5} - 3.5×10^{-4}
Landfill modeling data	0.007 - 0.12	0.008 - 0.044[f]	3.1×10^{-7} - 1.7×10^{-6}
Drinking water ingestion			
Monitoring data[b]	0.073 - 10.2	<4.4[g]	$<1.7 \times 10^{-4}$
Ground-water modeling data	0 - 0.2	$<3.0 \times 10^{-8}$[h]	$<1.2 \times 10^{-12}$
Food ingestion			
Adults[c]	68.1	68.1	2.7×10^{-3}
Toddlers[c]	22.0	22.0	4.4×10^{-3}
Infants[c]	5.1	5.1	1.7×10^{-3}
Freshwater fish eaters[i]	<53.7	<53.7	$<2.1 \times 10^{-3}$
Dacthal-treated crops[j]	<83 - 800	<4.2 - 40	$<1.0 \times 10^{-3}$ - 4.4×10^{-3}
Chlorothalonil-treated crops[j]	<14 - 630	<0.7 - 32	$<2.6 \times 10^{-4}$ - 6.0×10^{-4}
Picloram-treated crops[j]	<0.8 - 10.5	<0.01 - 0.11	$<2.4 \times 10^{-6}$ - 9.6×10^{-6}
PCNB-treated crops[j]	<1.5 - 41	<0.08 - 2.1	$<2.7 \times 10^{-5}$ - 1.4×10^{-4}

[a]With the exception of one high air value, estimated exposures range from <0.692 to 6.92 ug/yr (see Table 6-2).
[b]Range based on mean values reported in Oliver and Nicol (1982) and Barquet et al. (1981).
[c]Based on 1982-1984 FDA total diet study estimates.
[d]Overall mean of 18 city surveys listed in Table 7-2.
[e]Range of estimated exposures based on maximum annual concentrations within 50 km radius of an incinerator achieving 99.99 percent destruction of HCB.
[f]Range of estimated exposures from landfill with a 6-inch clay cap containing 1,000 ppm HCB waste.
[g]Assumes most water has less than 6 ng/l HCB.
[h]Estimated drinking water exposures ≥100 meters horizontal distance from landfill containing 1,000 ppm HCB waste.
[i]Assumes consumption of 14.7 grams of fish daily. Fish are assumed to contain less than 0.01 ug/g HCB (wet weight).
[j]The "best estimate" columns assume that less than 5 percent of target crops are treated with dacthal, PCNB, or chlorothalonil, and that less than 1 percent of target crops are treated with picloram.

7.1.1 Ambient Monitoring Data

Atmospheric HCB concentrations in urban areas reported in the literature range from 4.4 ng/m^3 in Greenville, Mississippi, to less than 0.1 ng/m^3 in Fort Collins, Colorado. HCB concentrations in urban areas along with the estimated annual inhalation exposure are presented in Table 7-2.

Based on the assumptions presented above, annual exposures were found to range from 0.69 to 30.4 ug/yr. With the exception of Greenville, Mississippi, all estimated mean exposures were less than 7 ug/yr.

7.1.2 Ambient Air Concentrations near Industrial Incinerators Releasing HCB

Dispersion modeling was performed to estimate HCB concentrations downwind of seven industrial incinerators that may be releasing HCB. Predicted maximum annual concentrations were found to vary from 5.9 x 10^{-6} to 1.09 x 10^{-2} ug/m^3. The HCB concentrations along with the estimated annual inhalation exposures are presented in Table 7-3. Based on the assumptions presented above, annual exposures for all cases were found to range from 0.04 to 90.0 ug/yr; best estimate exposures ranged from 0.4 to 9.0 ug/yr.

7.1.3 Ambient Air Concentrations near a Landfill Containing HCB

Modeling work was done to estimate the ambient air concentrations resulting from the volatilization of HCB from a landfill. Concentrations were estimated for landfills near Memphis, Tennessee, and Tacoma, Washington. The maximum annual average intra-ring concentrations and the estimated individual inhalation exposures are presented in Table 7-4. Concentrations range from 9.72 x 10^{-7} to 1.78 x 10^{-5} ng/m^3, and estimated individual exposures range from 6.7 x 10^{-3} to 1.23 x 10^{-1} ug/yr.

As part of the modeling work, inhalation exposures were calculated for each segment of the population and across all sector segments around the two landfills. The assumptions used to estimate inhalation exposures were similar to those used in the previous scenarios. The maximum cumulative inhalation exposures were 8.7 ug/yr for the Memphis, Tennessee, site and 1.3 ug/yr for the Tacoma, Washington, site (GSC 1986). A complete discussion of this work is presented in Appendix F.

7.2 Drinking Water Exposure

Drinking water exposures were estimated using monitoring data of HCB levels in finished municipal drinking water and using modeled

Table 7-2. Annual Inhalation Exposure to HCB

City	Mean air concentration[a] (ng/m^3)	Annual inhalation exposure (ug/yr)[b]	Survey year
Ft. Collins, CO	<0.1	<0.69	1975/76
Harrisburg, PA	0.1	0.69	1975/76
Jackson, MS	<0.1	0.69	1975/76
Lafayette, IN	0.2	1.38	1975/76
Greenville, MS	4.4	30.4	1977
	ND	ND	1978
Pasadena, CA	0.1	0.69	1977
	ND	ND	1978
	0.2	1.38	1979
Wheaton, IL	0.1	0.69	1977
Flathead, MT	ND	ND	1978
Cahohia, IL	0.3	2.08	1979
Columbia, SC	ND	ND	1979
Fresno, CA	1.0	6.92	1979
Harlingen, TX	0.6	4.15	1979
Houston, TX	0.9	6.23	1979
Leland, MS	0.9	6.23	1979
Lubbock, TX	0.2	1.38	1979

ND - Not detected; the detection limit is 0.1 ng/m^3.

[a] Monitoring data based on EPA surveys.
[b] Calculated (see text).

Source: Carey et al. (1985).

Table 7-3. Estimated Annual Inhalation Exposures (ug/yr) Based on Ambient Air Concentrations Downstream of Industrial HCB Incinerators[a]

Company	Plant location	Worst case exposures[b]		Best estimate exposures[c]		Best case exposures[d]	
		Incinerator A	Incinerator B	Incinerator A	Incinerator B	Incinerator A	Incinerator B
Diamond Shamrock Corp.	Deer Park, TX	69.2	45.0	6.9	4.5	0.69	0.45
Dow Chemical, U.S.A.	Freeport, TX	6.3	4.0	0.6	0.4	0.06	0.04
Dow Chemical, U.S.A.	Plaquemine, LA	37.3	25.6	3.7	2.6	0.37	0.26
Dow Chemical, U.S.A.	Pittsburg, CA	90.0	58.8	9.0	5.9	0.90	0.59
PPG Industries, Inc.	Lake Charles, LA	76.1	51.2	7.6	5.1	0.76	0.51
Vulcan Materials Co.	Geismar, LA	39.4	27.0	3.9	2.7	0.39	0.27
Vulcan Materials Co.	Wichita, KS	76.1	49.3	7.6	4.9	0.76	0.49

[a] See Section 6.1 for information on the ambient air concentrations.
[b] Assumes a 99.9 percnet DRE.
[c] Assumes a 99.99 percent DRE.
[d] Assumes a 99.999 percent DRE.

Table 7-4. Estimated Annual Inhalation Exposures Resulting from HCB Volatilization from a Landfill[a]

	Memphis, TN				Tacoma, WA			
Cap (in)	Maximum average intra-ring concentration 1/2-acre landfill (ug/m^3)	Estimated individual exposure (ug/yr)	Maximum average intra-ring concentration 1-acre landfill (ug/m^3)	Estimated individual exposure (ug/yr)	Maximum average intra-ring concentration 1/2-acre landfill (ug/m^3)	Estimated individual exposure (ug/yr)	Maximum average intra-ring concentration 1-acre landfill (ug/m^3)	Estimated individual exposure (ug/yr)
0	1.01×10^{-5}	7.0×10^{-2}	1.74×10^{-5}	1.2×10^{-1}	1.00×10^{-5}	6.9×10^{-2}	1.78×10^{-5}	1.23×10^{-1}
6	1.11×10^{-6}	7.7×10^{-3}	1.92×10^{-6}	1.3×10^{-2}	3.58×10^{-6}	2.5×10^{-2}	6.34×10^{-6}	4.4×10^{-2}
12	1.06×10^{-6}	7.3×10^{-3}	1.84×10^{-6}	1.3×10^{-2}	3.42×10^{-6}	2.4×10^{-2}	6.05×10^{-6}	4.2×10^{-2}
24	9.72×10^{-7}	6.7×10^{-3}	1.68×10^{-6}	1.2×10^{-2}	3.12×10^{-6}	2.2×10^{-2}	5.52×10^{-6}	3.8×10^{-2}

[a] Concentrations in air and resulting exposures are based on a concentration of HCB in the sludge of 1000ppm.

concentrations of HCB level in ground water. For all estimations, a daily drinking water intake of 2 liters per day (Versar 1983), 365 days, was assumed. A separate subsection is presented for each scenario.

7.2.1 Monitoring Data

Four studies were found that presented monitoring results of drinking water supplies; these results were presented in Table 5-26. The areas that were monitored were Lake Ontario (near Niagara Falls, New York); Dade County, Florida; and USEPA Region V; and a Nationwide Survey (96 locations) by EPA's Office of Drinking Water.

The study of Lake Ontario presented a mean concentration (three samples) of 0.1 ppt, or 1×10^{-4} ug/l. Major sources of HCB pollution here seem to be chemical waste dump leachate and direct industrial effluents around Niagara Falls, New York (Oliver and Nicol 1982). The estimated annual HCB intake is 7.3×10^{-2} ug/yr.

The mean concentration of ten samples from Dade County, Florida, an area of extensive pesticide use (Barquet et al. 1981), was 14 ng/l, corresponding to an estimated annual HCB intake of 10.2 ug/yr. The lowest concentration was below detection limits (Barquet et al. 1981).

The Region V study was based on 83 samples; however, only two of the samples had detectable levels of HCB. The two detectable levels were 0.004 and 0.006 ug/l, which correspond to an estimated annual exposure of 2.9 ug/yr and 4.4 ug/yr, respectively. The EPA nationwide survey of 96 locations found no HCB at a quantification limit of 0.2 ug/l.

7.2.2 Ground-Water Modeling

Estimated HCB concentrations in ground water that have resulted from landfill releases were presented in Section 6. It is assumed that this contaminated ground water is used as drinking water, and thus individual drinking water exposures were estimated; the results are presented in Table 7-5.

Estimated annual individual exposures range from 0 ug/yr to 2.0×10^{-1} ug/yr.

7.3 Ingestion Exposure

The food ingestion scenario is based on the FDA Total Diet Study. The Total Diet Study was initiated by the Food and Drug Administration in the mid-1960s. It comprises analyses of ready-to-eat foods for residues

Table 7-5. Estimated Annual Individual Exposures Resulting from the Consumption of Contaminated Ground Water[a,b]

Horizontal distance from center of landfill (m)	Memphis, TN				Tacoma, WA			
	Concentrations from the 1/2-acre landfill (ug/l)	Estimated exposures (ug/yr)	Concentrations from the 1-acre landfill (ug/l)	Estimated exposures (ug/yr)	Concentrations from the 1/2-acre landfill (ug/l)	Estimated exposures (ug/yr)	Concentrations from the 1-acre landfill (ug/l)	Estimated exposures (ug/yr)
0	1.1×10^{-6}	8.0×10^{-4}	1.1×10^{-6}	8.0×10^{-4}	2.7×10^{-4}	2.0×10^{-1}	2.7×10^{-4}	2.0×10^{-1}
20	7.7×10^{-7}	5.6×10^{-4}	1.0×10^{-6}	7.3×10^{-4}	2.6×10^{-4}	1.9×10^{-1}	2.7×10^{-4}	2.0×10^{-1}
40	6.0×10^{-8}	4.4×10^{-5}	2.0×10^{-7}	1.5×10^{-4}	0.0	0.0	5.1×10^{-9}	3.7×10^{-1}
60	4.3×10^{-9}	3.1×10^{-6}	1.5×10^{-8}	1.1×10^{-5}	0.0	0.0	0.0	0.0
80	2.2×10^{-10}	1.6×10^{-7}	9.5×10^{-10}	6.9×10^{-7}	0.0	0.0	0.0	0.0
100	7.3×10^{-12}	5.3×10^{-9}	3.9×10^{-11}	2.8×10^{-8}	0.0	0.0	0.0	0.0
120	1.5×10^{-13}	1.1×10^{-10}	1.0×10^{-12}	7.3×10^{-10}	0.0	0.0	0.0	0.0
140	1.8×10^{-14}	1.3×10^{-11}	1.6×10^{-14}	1.2×10^{-11}	0.0	0.0	0.0	0.0
160	4.4×10^{-18}	3.2×10^{-15}	1.2×10^{-16}	8.8×10^{-14}	0.0	0.0	0.0	0.0
180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Based on the consumption of 2 liters/day, 365 days/yr.

[b]Concentrations of HCB in ground water and the resulting exposures were based on the assumption that HCB was present in the waste sludge at a concentration of 1,000 ppm.

of pesticides, industrial chemicals, radionuclides, and essential element content. Analysis for HCB residues began in 1970, using FDA analytical methods with a quantification limit of 0.001 ppm (FDA 1971).

Samples consisted of a 2- to 4-week food supply collected in the form of market basket samples from several retail stores in each of the four FDA regions (see Figure 5-1). The collected foods were separated into classes of commodities; 12 for the adult diet and 11 for the infant and toddler diets. The foods were then prepared as for consumption, and the food items in each class were blended prior to analysis.

Results of the 1982-1984 survey included HCB levels of 0.0027 ug/kg/day for adults, 0.0044 ug/kg/day for toddlers, and 0.0017 ug/kg/day for infants. Adults are defined as males age 16 to 19, since this group is thought to have the highest food consumption rate. Toddlers are 2 years old, and infants are 6 months old.

Multiplying the above results by 365 days/year, the estimated annual intake is 0.99 ug/kg for adults, 1.6 ug/kg for toddlers, and 0.62 ug/kg for infants. To estimate annual exposures, the following average body weights were used: 69.1 kg for adults, 13.7 kg for toddlers, and 8.2 kg for infants. Consequently, estimated annual exposures to HCB are 68.1 ug, 22.0 ug, and 5.1 ug for adults, toddlers, and infants, respectively.

7.4 Exposure to HCB-Contaminated Fish

Based on the fish sampling data from the Fish and Wildlife Service (see Section 5.3), an exposure scenario was developed for the ingestion of contaminated fish. However, it is difficult to determine what proportion of dietary HCB intake results from eating contaminated fish, since the FDA studies report only the combined total of fish and meat. According to Nelson and Yang (1984), average daily fish consumption is 14.7 g/day. Freshwater fish contamination by HCB averages less than 0.01 ug/g on a wet-weight bases (Schmitt et al. 1983). Consequently, total annual consumption of fish is 5,370 g/yr, which corresponds to ingestion of less than 53.7 ug of HCB per year. This assumes that, as a worst case, all edible fish are contaminated at the level reported for freshwater fish.

7.5 Exposure to HCB in Pesticide-Contaminated Food

Exposure to HCB in four pesticides via food ingestion was estimated using draft routine chronic analyses from the Office of Pesticide Programs, Hazard Evaluation Division's Tolerance Assessment System.

Based on the USDA 1977 and 1978 food consumption surveys for several hundred food products, this system estimates the dietary intakes for 22 subpopulations in the United States. The system was used to estimate the dietary intake of HCB that may be present on crops that have been treated with pesticides known to contain HCB. Only those pesticides for which EPA has established tolerances and that are known to contain HCB were considered. These are dacthal, chlorothalonil, picloram, and pentachloronitrobenzene (PCNB). The assumed HCB contamination levels in the pesticides are presented in Table 7-6 along with the estimated maximum contribution of the above four pesticides to the annual dietary intake of HCB. These estimates assume that HCB is present in or on the crop in the same proportion relative to the pesticide as it is found in the original pesticide product. If the pesticide dissipates from the crop at a faster rate than HCB, then the estimated HCB concentrations in or on the crops may be underestimated. Tables 7-7 through 7-10 provide subpopulation breakdowns of these same data for each of the four pesticides. As can be seen in these tables, dacthal may contribute the largest amount of HCB to the diet among the four pesticides considered.

7.6 Pharmacokinetic Modeling of NHATS Survey Data

Scott (1985, 1986) used a physiologically-based pharmacokinetic model to estimate the steady-state HCB exposures required to yield the human adipose HCB levels observed in the NHATS survey data for the 1980s. The pharmacokinetic model has been described by Feder et al. (1985) and by Yesair et al. (1985). Two underlying assumptions of Scott's analysis are that adipose tissue levels represent steady-state levels and that a linear relationship exists between exposure and deposition of HCB in adipose tissue.

The steady-state exposures (in ug/kg/day) estimated by Scott (1985, 1986) to result in the adipose HCB levels corresponding to the 50th and 90th percentile NHATS values are presented in Table 7-11 and Table 7-12 for males and females, respectively. As can be seen in the tables, the estimated exposures for males are, in general, slightly higher than for females; the exceptions to this are 90th percentile values in some census divisions for the older age group. In most census divisions and for both sexes, the older age group has higher estimated exposures than the younger age group. The most notable exceptions are the West South Central Division for females and the Mountain Division for males where both the 50th and 90th percentiles for the younger age group are higher. The Pacific Census Division has overall higher estimated exposures for both sexes when compared to the total U.S. and to the other census divisions.

Table 7-6. Estimated Maximum Contribution of Selected Pesticides to Annual Dietary Intake of HCB[a]

Pesticide	Estimated dietary intake of active ingredient[b] (mg/yr)	HCB contamination[c] (percent)	Estimated dietary intake of HCB[d] (ug/yr)
Dacthal	235	<0.3	$<7.1 \times 10^{2}$
Chlorothalonil	324	<0.05	$<1.6 \times 10^{2}$
Picloram	45.8	<0.02	<9.2
PCNB	4.96×10^{-2}	<0.5	$<3.7 \times 10^{1}$

[a]Based on the U.S. population from the contiguous 48 states.
[b]Estimated from USEPA (1985) assuming a body weight of 68 kg and ingestion 365 days per year.
[c]Maximum contamination levels as specified in agreements between EPA and the manfacturers.
[d]These estimates assume that all target crops potentially treated with the pesticides are treated. More reasonable approximations are that only 5 percent of the crops potentially treated with dacthal, PCNB or chlorothalonil and 1 percent of the crops potentially treated with picloam are in fact treated.

Table 7-7. Estimated Maximum Annual Dietary Intake of HCB Associated with Dacthal

Population subgroup	Estimated dietary intake of active ingredient (mg/kg/yr)	Estimated dietary intake of HCB[a,b] (ug/kg/yr)	Estimated individual body weight[c] (kg)	Estimated individual dietary intake of HCB[b] (ug/yr)
U.S. Pop. - 48 states - all seasons	3.46	< 10.4	68	$< 7.1 \times 10^2$
U.S. Pop. - spring season	3.34	< 10.0	68	$< 6.8 \times 10^2$
U.S. Pop. - summer season	3.50	< 10.5	68	$< 7.1 \times 10^2$
U.S. Pop. - fall season	3.53	< 10.6	68	$< 7.2 \times 10^2$
U.S. Pop. - winter season	3.48	< 10.4	68	$< 7.1 \times 10^2$
Northeast region	3.34	< 10.0	68	$< 6.8 \times 10^2$
North Central region	3.53	< 10.6	68	$< 7.2 \times 10^2$
Southern region	3.39	< 10.2	68	$< 6.9 \times 10^2$
Western region	3.63	< 10.9	68	$< 7.4 \times 10^2$
Hispanics	3.93	< 11.8	68	$< 8.0 \times 10^2$
Non-Hispanic whites	3.44	< 10.7	68	$< 7.3 \times 10^2$
Non-Hispanic blacks	3.34	< 10.0	68	$< 6.8 \times 10^2$
Non-Hispanics other than whites and blacks	3.45	< 10.4	68	$< 7.1 \times 10^2$
Nursing infants (less than 1 year old)	3.65	< 11.0	7.5	$< 8.3 \times 10^1$
Non-nursing infants (at least 1 year old)	10.6	< 31.9	9.8	$< 3.1 \times 10^2$
Females (13+ years, pregnant, not nursing)	2.53	< 7.6	53.8	$< 4.1 \times 10^2$
Females (13+ years, nursing)	3.09	< 9.3	53.8	$< 5.0 \times 10^2$
Children (1-6 years)	7.12	< 21.4	14.4	$< 3.1 \times 10^2$
Children (7-12 years)	5.11	< 15.3	31.2	$< 4.8 \times 10^2$
Males (13-19 years)	3.50	< 10.5	61.7	$< 6.5 \times 10^2$
Females (13-19 years, not pregnant or nursing)	2.98	< 8.9	53.8	$< 4.8 \times 10^2$
Males (20+ years)	2.63	< 7.9	69	$< 5.5 \times 10^2$
Females (20+ years, not pregnant or nursing)	2.52	< 7.6	63.7	$< 4.8 \times 10^2$

[a]Based on < 0.3% contamination.

[b]These estimates assume that all food crops potentially treated with dacthal are treated. A more reasonable approximation is that only 5 percent of the potentially treated crops are in fact treated.

[c]Derived from Versar (1983).

Table 7-8. Estimated Maximum Annual Dietary Intake of HCB Associated with Chlorothalonil

Population subgroup	Estimated dietary intake of active ingredient (mg/kg/yr)	Estimated dietary intake of HCB[a,b] (ug/kg/yr)	Estimated individual body weight[c] (kg)	Estimated individual dietary intake of HCB[b] (ug/yr)
U.S. Pop. - 48 states - all seasons	4.78	< 2.4	68	$< 1.6 \times 10^2$
U.S. Pop. - spring season	4.64	< 2.3	68	$< 1.5 \times 10^2$
U.S. Pop. - summer season	5.40	< 2.7	68	$< 1.8 \times 10^2$
U.S. Pop. - fall season	4.56	< 2.3	68	$< 1.5 \times 10^2$
U.S. Pop. - winter season	4.49	< 2.2	68	$< 1.5 \times 10^2$
Northeast region	4.85	< 2.4	68	$< 1.6 \times 10^2$
North Central region	4.82	< 2.4	68	$< 1.6 \times 10^2$
Southern region	4.42	< 2.2	68	$< 1.5 \times 10^2$
Western region	5.15	< 2.6	68	$< 1.8 \times 10^2$
Hispanics	4.96	< 2.5	68	$< 1.7 \times 10^2$
Non-Hispanic whites	4.89	< 2.4	68	$< 1.6 \times 10^2$
Non-Hispanic blacks	3.80	< 1.9	68	$< 1.3 \times 10^2$
Non-Hispanics other than whites and blacks	5.33	< 2.7	68	$< 1.8 \times 10^2$
Nursing infants (less than 1 year old)	3.80	< 1.9	7.5	$< 1.4 \times 10^1$
Non-nursing infants (at least 1 year old)	8.07	< 4.0	9.8	$< 3.9 \times 10^1$
Females (13+ years, pregnant, not nursing)	3.91	< 2.0	53.8	$< 1.1 \times 10^2$
Females (13+ years, nursing)	4.53	< 2.3	53.8	$< 1.2 \times 10^2$
Children (1-6 years)	8.72	< 4.4	14.4	$< 6.3 \times 10^2$
Children (7-12 years)	6.90	< 3.4	31.2	$< 1.1 \times 10^2$
Males (13-19 years)	4.64	< 2.3	61.7	$< 1.4 \times 10^2$
Females (13-19 years, not pregnant or nursing)	4.12	< 2.1	53.8	$< 1.1 \times 10^2$
Males (20+ years)	3.80	< 2.0	69	$< 1.4 \times 10^2$
Females (20+ years, not pregnant or nursing)	3.91	< 2.0	63.7	$< 1.3 \times 10^2$

[a]Based on < 0.05% contamination.

[b]These estimates assume that all food crops potentially treated with chlorothalonil are in fact treated. A more reasonable approximation is that only 5 percent of the potentially treated crops are in fact treated.

[c]Derived from Versar (1983).

Table 7-9. Estimated Maximum Annual Dietary Intake of HCB Associated with Picloram

Population subgroup	Estimated dietary intake of active ingredient (mg/kg/yr)	Estimated dietary intake of HCB[a,b] (ug/kg/yr)	Estimated individual body weight[c] (kg)	Estimated individual dietary intake of HCB[b] (ug/yr)
U.S. Pop. - 48 states - all seasons	0.67	$< 1.3 \times 10^{-1}$	68	< 9.1
U.S. Pop. - spring season	0.65	$< 1.3 \times 10^{-1}$	68	< 8.8
U.S. Pop. - summer season	0.67	$< 1.3 \times 10^{-1}$	68	< 9.1
U.S. Pop. - fall season	0.69	$< 1.4 \times 10^{-1}$	68	< 9.3
U.S. Pop. - winter season	0.68	$< 1.4 \times 10^{-1}$	68	< 9.2
Northeast region	0.69	$< 1.4 \times 10^{-1}$	68	< 9.3
North Central region	0.69	$< 1.4 \times 10^{-1}$	68	< 9.3
Southern region	0.62	$< 1.2 \times 10^{-1}$	68	< 8.4
Western region	0.69	$< 1.4 \times 10^{-1}$	68	< 9.3
Hispanics	0.77	$< 1.5 \times 10^{-1}$	68	<10.5
Non-Hispanic whites	0.68	$< 1.4 \times 10^{-1}$	68	< 9.2
Non-Hispanic blacks	0.62	$< 1.2 \times 10^{-1}$	68	< 8.4
Non-Hispanics other than whites and blacks	0.69	$< 1.4 \times 10^{-1}$	68	< 9.3
Nursing infants (less than 1 year old)	0.51	$< 1.0 \times 10^{-1}$	7.5	< 0.8
Non-nursing infants (at least 1 year old)	1.75	$< 3.5 \times 10^{-1}$	9.8	< 3.4
Females (13+ years, pregnant, not nursing)	0.47	$< 9.4 \times 10^{-2}$	53.8	< 5.1
Females (13+ years, nursing)	0.58	$< 1.2 \times 10^{-1}$	53.8	< 6.2
Children (1-6 years)	1.57	$< 3.1 \times 10^{-1}$	14.4	< 4.5
Children (7-12 years)	1.06	$< 2.1 \times 10^{-1}$	31.2	< 6.6
Males (13-19 years)	0.73	$< 1.5 \times 10^{-1}$	61.7	< 9.0
Females (13-19 years, not pregnant or nursing)	0.58	$< 1.2 \times 10^{-1}$	53.8	< 6.2
Males (20+ years)	0.51	$< 1.0 \times 10^{-1}$	69	< 7.0
Females (20+ years, not pregnant or nursing)	0.44	$< 8.8 \times 10^{-2}$	63.7	< 5.6

[a]Based on < 0.02% contamination.

[b]These estimates assume that all food crops potentially treated with picloram are in fact treated. A more reasonable approximation is that only 1 percent of the potentially treated crops are in fact treated.

[c]Derived from Versar (1983).

Table 7-10. Estimated Maximum Annual Dietary Intake of HCB Associated with PCNB

Population subgroup	Estimated dietary intake of active ingredient (mg/kg/yr)	Estimated dietary intake of HCB[a,b] (ug/kg/yr)	Estimated individual body weight[c] (kg)	Estimated individual dietary intake of HCB[b] (ug/yr)
U.S. Pop. - 48 states - all seasons	0.11	< 0.55	68	$< 3.7 \times 10^1$
U.S. Pop. - spring season	NA	NA	68	NA
U.S. Pop. - summer season	NA	NA	68	NA
U.S. Pop. - fall season	NA	NA	68	NA
U.S. Pop. - winter season	NA	NA	68	NA
Northeast region	NA	NA	68	NA
North Central region	NA	NA	68	NA
Southern region	NA	NA	68	NA
Western region	NA	NA	68	NA
Hispanics	0.12	< 0.60	68	$< 4.1 \times 10^1$
Non-Hispanic whites	0.11	< 0.55	68	$< 3.7 \times 10^1$
Non-Hispanic blacks	0.10	< 0.50	68	$< 3.4 \times 10^1$
Non-Hispanics other than whites and blacks	0.10	< 0.50	68	$< 3.4 \times 10^1$
Nursing infants (less than 1 year old)	0.04	< 0.20	7.5	< 1.5
Non-nursing infants (at least 1 year old)	0.12	< 0.60	9.8	< 5.9
Females (13+ years, pregnant, not nursing)	0.09	< 0.45	53.8	$< 2.4 \times 10^1$
Females (13+ years, nursing)	0.10	< 0.50	53.8	$< 2.7 \times 10^1$
Children (1-6 years)	0.21	< 1.05	14.4	$< 1.5 \times 10^1$
Children (7-12 years)	0.17	< 0.85	31.2	$< 2.6 \times 10^1$
Males (13-19 years)	0.12	< 0.60	61.7	$< 3.7 \times 10^1$
Females (13-19 years, not pregnant or nursing)	0.10	< 0.50	53.8	$< 2.7 \times 10^1$
Males (20+ years)	0.09	< 0.45	69	$< 3.1 \times 10^1$
Females (20+ years, not pregnant or nursing)	0.08	< 0.40	63.7	$< 2.5 \times 10^1$

NA = Data not available.

[a]Based on < 0.5% contamination.

[b]These estimates assume that all food crops potentially treated with PCNB are in fact treated. A more reasonable approximation is that only 5 percent of the potentially treated crops are in fact treated.

[c]Derived from Versar (1983).

Table 7-11. Estimated Steady-State Exposure Levels Resulting in the 50th and 90th Percentile NHATS Adipose Tissue Concentrations Observed in Males (1980s NHATS Data)

Census division/ age group (yrs)	Estimated steady-state exposure (ug/kg/day)[a]		Required ambient air HCB concentration (ng/m^3)[b]		Required drinking water HCB concentration (ug/l)[c]	
	50th percentile	90th percentile	50th percentile	90th percentile	50th percentile	90th percentile
Northeast						
15-44	0.006	0.010	18	29	0.21	0.35
45+	0.006	0.028	18	82	0.21	0.98
Middle Atlantic						
15-44	0.007	0.015	20	44	0.24	0.52
45+	0.008	0.024	23	70	0.28	0.84
South Atlantic						
15-44	0.006	0.010	18	29	0.21	0.35
45+	0.006	0.012	18	35	0.21	0.42
East North Central						
15-44	0.007	0.014	20	41	0.24	0.49
45+	0.007	0.013	20	38	0.24	0.46
East South Central						
15-44	0.006	0.007	18	20	0.21	0.24
45+	0.005	0.009	15	26	0.18	0.32

Table 7-11. (Continued)

Census division/ age group (yrs)	Estimated steady-state exposure (ug/kg/day)[a]		Required ambient air HCB concentration (ng/m^3)[b]		Required drinking water HCB concentration (ug/l)[c]	
	50th percentile	90th percentile	50th percentile	90th percentile	50th percentile	90th percentile
West North Central						
15-44	0.006	0.011	18	32	0.21	0.38
45+	0.007	0.013	20	38	0.24	0.46
West South Central						
15-44	0.007	0.016	20	47	0.24	0.56
45+	0.007	0.017	20	50	0.24	0.60
Mountain						
15-44	0.012	0.018	35	52	0.42	0.63
45+	0.008	0.012	23	35	0.28	0.42
Pacific						
15-44	0.011	0.021	32	61	0.38	0.74
45+	0.010	0.044	29	128	0.35	1.54
Total U.S.						
15-44	0.006	0.013	18	38	0.21	0.46
45+	0.007	0.014	20	41	0.24	0.49

[a]Estimated exposures were calculated using the human physiologic pharmacokinetic model for hexachlorobenzene. This model is described by Feder et al. (1985) and Yesair et al. (1985). Source: Scott (1985, 1986).

[b]Assumes inhalation rate of 24 m^3/day, a body weight of 70 kg, and 100 percent HCB absorption.

[c]Assumes ingestion of 2 liters of water/day, a body weight of 70 kg, and 100 percent HCB absorption.

Table 7-12. Estimated Steady-State Exposure Levels Resulting in the 50th and 90th Percentile NHATS Adipose Tissue Concentrations Observed in Females (1980s NHATS Data)

Census division/ age group (yrs)	Estimated steady-state exposure (ug/kg/day)[a]		Required ambient air HCB concentration (ng/m^3)[b]		Required drinking water HCB concentration (ug/l)[c]	
	50th percentile	90th percentile	50th percentile	90th percentile	50th percentile	90th percentile
Northeast						
15-44	0.004	0.004	10	10	0.12	0.12
45+	0.004	0.010	10	25	0.12	0.30
Middle Atlantic						
15-44	0.004	0.009	10	23	0.12	0.27
45+	0.005	0.029	12	72	0.15	0.87
South Atlantic						
15-44	0.003	0.006	8	15	0.09	0.18
45+	0.004	0.014	10	35	0.12	0.42
East North Central						
15-44	0.002	0.008	5	20	0.06	0.24
45+	0.004	0.008	10	20	0.12	0.24
East South Central						
15-44	0.002	0.005	5	12	0.06	0.15
45+	0.004	0.010	10	25	0.12	0.30

Table 7-12. (Continued)

Census division/ age group (yrs)	Estimated steady-state exposure (ug/kg/day)[a]		Required ambient air HCB concentration (ng/m^3)[b]		Required drinking water HCB concentration (ug/l)[c]	
	50th percentile	90th percentile	50th percentile	90th percentile	50th percentile	90th percentile
West North Central						
15-44	0.004	0.016	10	40	0.12	0.48
45+	0.006	0.010	15	25	0.18	0.30
West South Central						
15-44	0.005	0.011	12	28	0.15	0.33
45+	0.004	0.007	10	18	0.12	0.21
Mountain						
15-44	0.004	0.009	10	23	0.12	0.27
45+	0.007	0.014	18	35	0.21	0.42
Pacific						
15-44	0.004	0.008	10	20	0.12	0.24
45+	0.009	0.059	23	148	0.27	1.77
TOTAL U.S.						
15-44	0.004	0.007	10	18	0.12	0.21
45+	0.005	0.012	12	30	0.15	0.36

[a]Estimated exposures were calculated using the human physiologic pharmacokinetic model for hexachlorobenzene. This model is described by Feder et al. (1985) and Yesair et al. (1985). Source: Scott (1985, 1986).

[b]Assumes inhalation rate of 24 m^3/day, a body weight of 60 kg, and 100 percent HCB absorption.

[c]Assumes ingestion of 2 liters of water/day, a body weight of 60 kg, and 100 percent HCB absorption.

Tables 7-11 and 7-12 also contain estimates of the steady-state ambient air and drinking water HCB concentrations that would be required to result in the steady-state exposures estimated by Scott (1985, 1986) assuming, as a worst case, 100 percent absorption of inhaled or ingested HCB. Although the estimated required HCB concentrations are very low, they are generally much higher than the concentrations of HCB that have been measured in these two environmental media.

For example, to obtain the 50th percentile exposure for the total U.S. of 0.004 to 0.007 ug/kg/day would require HCB air concentrations of 10 to 20 ng/m^3. The summary statistics of 18 ambient city surveys conducted by EPA that are summarized in Table 7-2 indicate that only one survey reported a mean HCB concentration higher than 1 ng/m^3. That high mean level was due to one high sample (45.5 ng/m^3); ten of the eleven other samples collected in that city had no detectable HCB (detection limit of 0.1 ng/m^3). Twelve of the 18 city surveys had mean HCB levels of 0.2 ng/m^3 or less which is 50 to 100 times lower than the concentration required to obtain the 50th percentile exposure estimated by Scott (1985, 1986).

Similarly, to obtain the 50th percentile exposure for the total U.S. would require HCB drinking water concentrations of 0.12 to 0.24 ug/l. The few monitoring results for HCB in drinking water that have been reported are summarized in Table 5-26 and in Section 7.2. HCB was detected in only 9 of 192 samples. At least seven of these positives were collected in areas where HCB contamination might reasonably be expected (i.e., areas with extensive pesticide use or industrial waste discharges and chemical waste landfills). The highest reported concentration, 0.068 ug/l, is at the low end of the range of concentrations that would be required to achieve the 50th percentile exposures estimated by Scott (1985, 1986). The bulk of the reported measurements are one to two orders of magnitude less than is required to achieve the 50th percentile exposure.

Unlike the reported measurements of HCB in air and water, the reported measurements of HCB intake via food do provide the necessary levels to achieve the exposures estimated by Scott (1985, 1986). The average adult intake of HCB estimated by FDA through their Total Diet Study for the late 1970s and early 1980s ranges from 0.002 to 0.004 ug/kg/day. This estimate compares quite well to the exposures estimated for the 50th percentile by Scott (1985, 1986) of 0.004 to 0.007 ug/kg/day.

7.7 References

Barquet A, Carmen M, Pfaffenberger CD. 1981. Determination of organochlorine pesticides and metabolites in drinking water, human blood serum, and adipose tissue. Journal of Toxicology and Environmental Health 7:469-479.

Carey AE, Dixon TE, Yang HSC. 1984. Environmental Exposure to hexachlorobenzene in the United States. Washington, DC: U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances.

FDA. 1971. The Food and Drug Administration's pesticide analytical manual. Washington, DC: U.S. Department of Health, Education, and Welfare, Food and Drug Administration.

Feder PI, Yesair DW, and Naber SJ. 1985. Pharmacokinetic applications to quantitative risk assessments. Draft report. Battelle, Columbus Division-Washington Operations. Prepared under EPA Contract No. 68-01-6721.

Freed JR, Chambers T, Christie WN, Carpenter CE. 1983. Methods for assessing exposure to chemical substances. Vol. 2. Methods for assessing exposure to chemical substances in the ambient environment. Washington, DC: U.S. Environmental Protection Agency. EPA 560/5-83-015.

GSC. 1986. Modeling inhalation exposure and groundwater contamination of hexachlorobenzene from landfills. Draft report. Washington, DC: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. EPA Contract No. 68-02-3968.

Nelson CB, Yang YY. 1984. An estimation of the daily food intake based on data from the 1977-1978 USDA nationwide food consumption survey. Washington, DC: U.S. Environmental Protection Agency, Office of Radiation Programs.

Oliver BG, Nicol KD. 1982. Chlorobenzenes in sediments, water, and selected fish from Lakes Superior, Huron, Erie, and Ontario. Environmental Science & Technology 16:532-536.

Schmitt CJ, Ribick MA, Ludke JL, May TW. 1983. National pesticide monitoring program: organochlorine residues in freshwater fish, 1976-79. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service Resource Publication 152.

Scott CS. 1985. Pharmacokinetically-derived environmental exposure estimates from adipose burdens of hexachlorobenzene. Washington, D.C.: U.S. Environmental Protection Agency, Office of Toxic Substances. Memorandum. October 4, 1985.

Scott CS. 1986. Estimated exposure levels to hexachlorobenzene for U.S. males. Washington, D.C.: U.S. Environmental Protection Agency, Office of Toxic Substances. Memorandum. January 16, 1986.

USEPA. 1985. Routine chronic analysis. Printout 7/31/85, Washington, DC: U.S. Environmental Protection Agency.

Versar Inc. 1983. Methodology for assessing exposures to chemical substances from drinking water. Draft report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. Contract No. 68-01-6271.

Yesair DW, Feder PI, Chin AE, Naber,SJ, Jupier-Goodman T, Scott CS, and Robinson PE. 1985. Development, evaulation and use of a pharmacokinetic model for hexachlorobenzene. Presented at IARC, International Symposium on Hexachlorobenzene. June 24-28, 1985.

8. CONCLUSIONS, HYPOTHESES, AND RECOMMENDATIONS

This section contains two hypotheses and several preliminary conclusions and recommendations. Section 8.1 presents the major conclusions of this report. Section 8.2 provides a hypothesis addressing the consistent increase in the detection frequencies of HCB found in fat samples taken from livestock from 1974 to 1978; this phenomenon was originally identified in Section 5.4. The second hypothesis, presented in Section 8.3, addresses the relatively high NHATS levels for HCB that were found in the Pacific Census Division. Finally, Section 8.4 presents the recommendations for this exposure assessment.

8.1 Conclusions

The conclusions are organized according to the major components of this report:

- Based on the available data, this study found that the vast majority of the HCB produced in this country is inadvertently generated during the manufacture of chlorinated solvents. Nearly all of the HCB from this source is either landfilled or incinerated, with most of the estimated releases being to landfills (95 percent), with considerably less to air (5 percent after incineration) and water (approximately 0 percent).

- The direct use of HCB as a fungicide appears to have ceased during 1985. However, HCB is known to still be inadvertently produced during the manufacture of five pesticides, and it is suspected of being produced during the manufacture of many others. Inadvertent production during pesticide manufacture appears to be the second most significant source of HCB.

- Although historical sources of HCB have not been quantified, they may also be a significant source. With the possible exception of landfills that contain HCB, other known historical sources (manufacture of certain other chlorinated compounds and municipal incineration) appear to be insignificant.

- Although HCB has apparently become widely distributed through volatilization, atmospheric transport, and precipitation, the principal paths for its environmental removal appear to be transport as an adsorbate on particulate matter in runoff and surface water and aquatic photolysis near the air-water interface. Contaminated particulate material may be washed out of the continental interior and deposited at shorelines and mouths of rivers where it can serve as a source of HCB to the biota. The short-term fate of HCB, however, is absorption to soils and sediments.

- FDA Total Diet Studies show a decrease in the daily intake of HCB for human toddlers and infants from the maximum, reached in 1977. The daily intake of HCB in the adult diet remained generally constant from 1971 to 1984. However, the HCB detection frequencies in the adult diet increased in 1976 up through 1979. Since 1979, detection frequencies in the adult human diet and daily intake of HCB have been decreasing.

- FDA surveillance monitoring data indicate that HCB is not commonly detected at the analytical limit of 0.01 mg/kg (less than 2 percent of the samples) in either foreign or domestic foods, although it has been much more frequently detected in certain commodity groups and individual products than in others. Groups experiencing more frequent detection include dairy products, meat and fish, and, to a lesser extent, peanuts, carrots, stringbeans, squash, lettuce, parsley, parsnips, and potatoes. HCB was only detected in 1 percent of the animal feed samples analyzed by the FDA between 1970 and 1976.

- As monitored by the USDA, the percent of meat and poultry samples in which HCB was detected ($\geq$0.01 mg/kg) increased significantly in 1974 and decreased significantly in 1978, producing a "hump" within the period 1974-1978. It is hypothesized that ingestion of feedstuffs contaminated with a higher than usual level of HCB was responsible.

- The NHATS data show that the HCB detection frequency in human adipose tissue has been slowly increasing over time (from 97.6 percent positive in 1974 to 100 percent positive in 1983). The mean residue levels show a quadratic trend over time, with the peak levels occurring in 1979. A comparison of the mean residue levels found no significant age, sex, or race differences; however, significant geographic differences were found with the West Census Region showing higher mean levels than the North Central and South Regions.

- Ambient monitoring data indicate that HCB is an ubiquitous chemical. It has been detected in all environmental media and in all areas of the country.

- Based on modeling estimates, it appears that HCB releases from clay-capped landfills result in very low HCB concentrations in ground water and ambient air downwind of the landfill. HCB concentrations in air downstream of an industrial incinerator may be more significant, depending on the quantity of HCB incinerated and the destruction efficiency of the incinerator.

- As indicated in Table 7-1, it appears that food ingestion is the major route of human exposure. For example, a comparison between best estimate exposures for food ingestion and inhalation and drinking water ingestion for adults indicates that food ingestion exposure is between 15 and 20 times more significant. The types of food classes that most commonly contain HCB are meat, fish, and dairy products.

- The pharmacokinetic modeling of the NHATS data (see Section 7.6) also indicated that food is probably the major route of human exposure. Estimates of the HCB concentrations in ambient air and drinking water that would be required to result in steady-state 50th percentile exposures estimated by the model are approximately one to two orders of magnitude higher than those actually found through ambient monitoring. However, the average adult intake of HCB estimated by FDA through their Total Diet Study (0.002 to 0.004 ug/kg/day) compares quite well to the 50th percentile exposures estimated by the model (0.004 to 0.007 ug/kg/day).

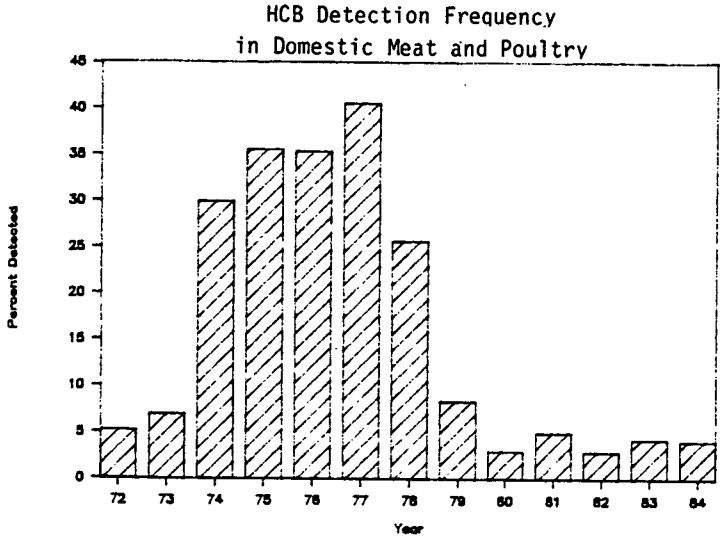
- Several important temporal trends were observed for human exposures; summaries of the relevant data are presented in Figures 8-1 and 8-2. The HCB levels in meat and poultry, the total HCB daily dietary intake, and the average levels of HCB in human adipose tissues all decreased slightly for the period 1979-1983. However, the percent of the population having detectable levels of HCB increased slightly during this period. The HCB detection frequency in domestic meat and poultry peaked between 1974 and 1978, daily dietary intake of HCB peaked in 1977-1978 (for all age groups combined), and the HCB levels in human adipose tissue were the highest between 1979 and 1981.

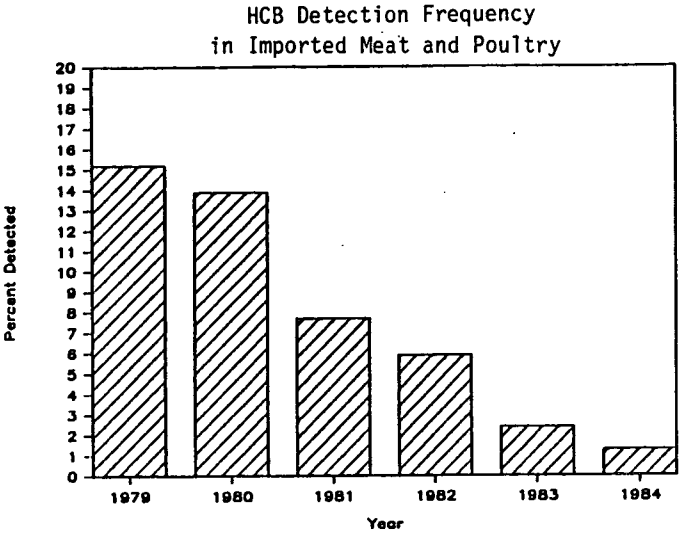
- No universal trends were observed for the detection frequency of HCB in wildlife; a summary of the available data is presented in Figure 8-3. The HCB detection frequency in ducks and fish peaked in 1976-1977, decreased in 1979, and remained relatively constant through the next sampling period. The HCB detection frequency in starlings has remained relatively constant from 1974 to 1982, although it was slightly higher in 1979.

8.2 The USDA "Hump"

8.2.1 Introduction

Statistical analysis of data on the detection of HCB residue levels in livestock has disclosed a significant temporal difference that grouped





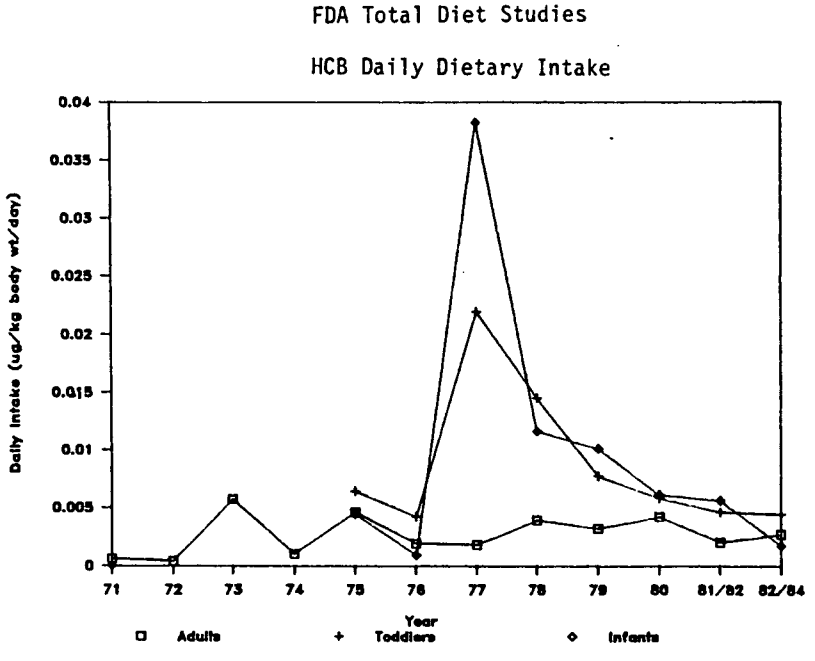
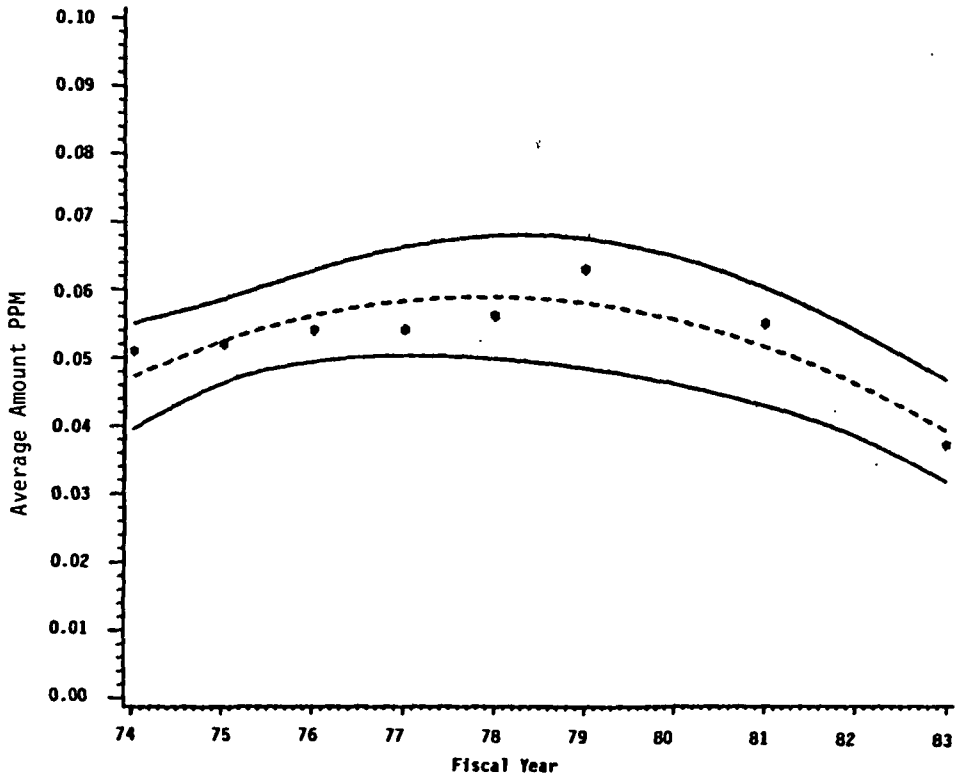
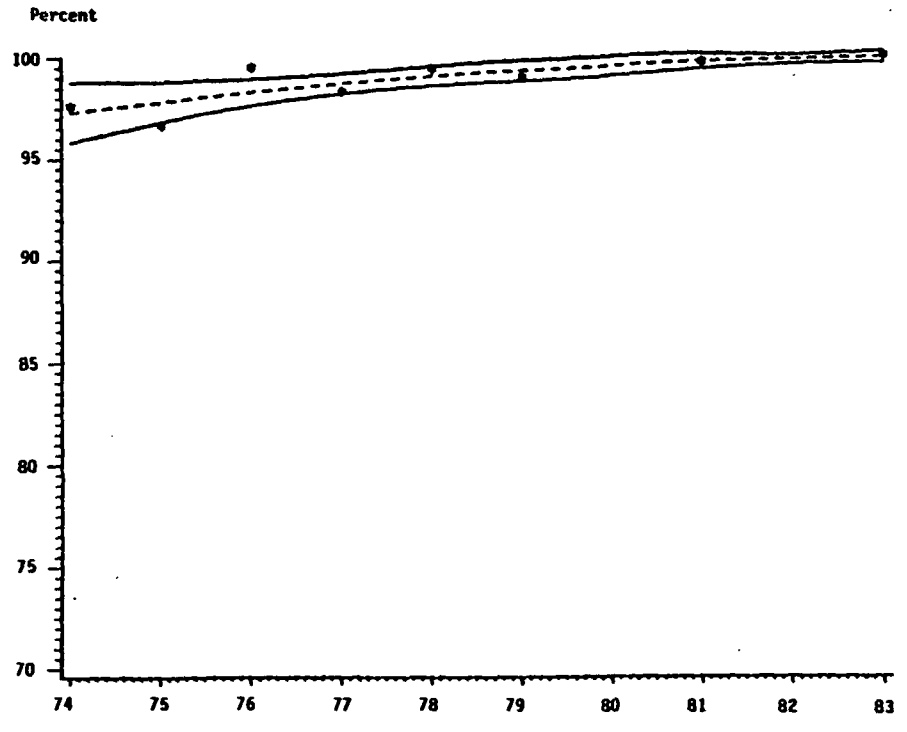


Figure 8-1. HCB detection frequency in meat and poultry and HCB daily dietary intake, 1971-1984.



Plot of national time trend and 95 percent confidence bands for the average amount of HCB.



Plot of national time trend and 95 percent confidence bands for the percent of population having detectable levels of HCB.

Figure 8-2. Plot of national time trend and 95 percent confidence bands for the average amount of HCB in adipose tissue and the percent of population having detectable levels of HCB.

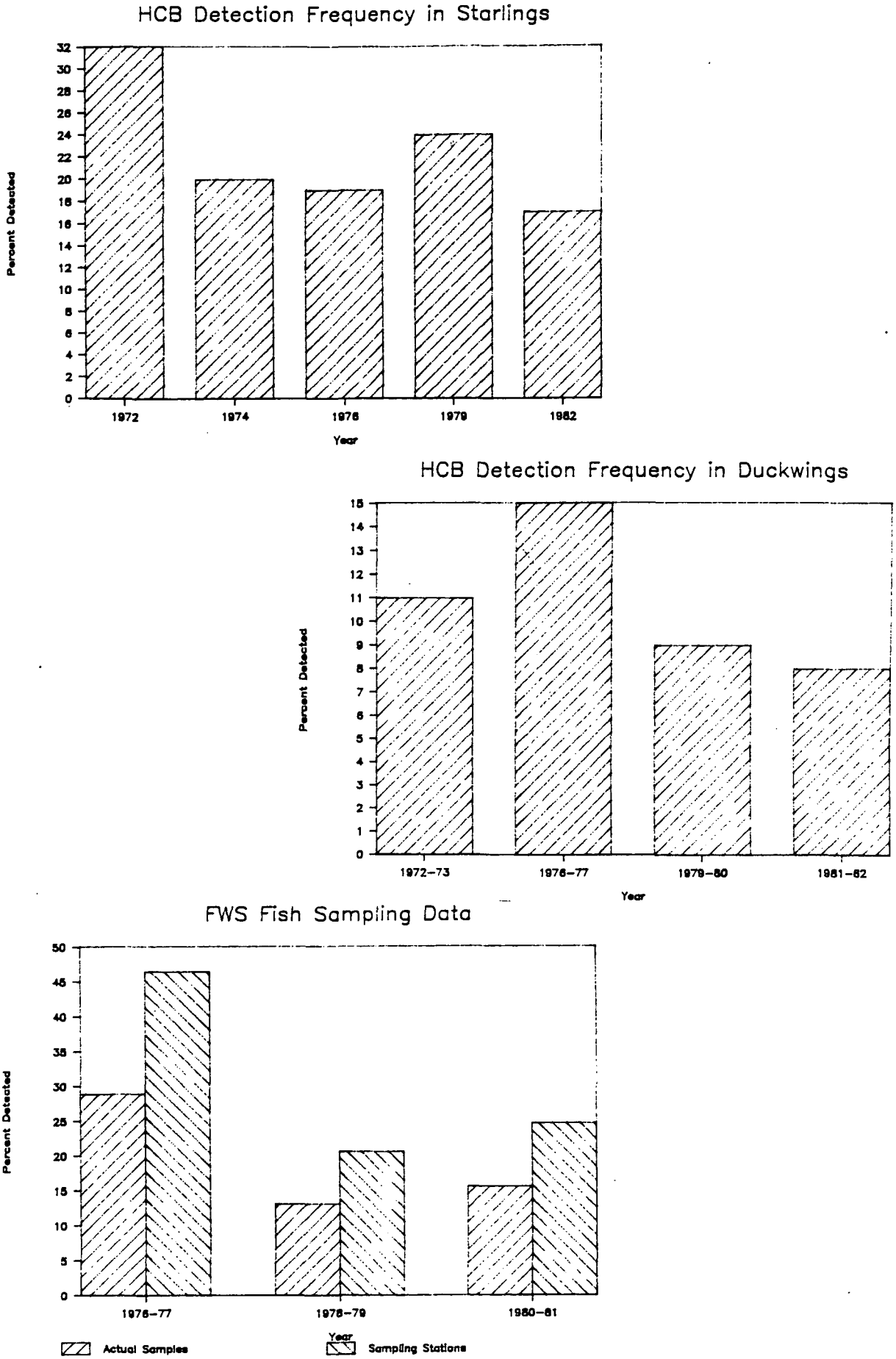


Figure 8-3. HCB detection frequency in starlings, duckwings, and fish.

the data into three periods: 1972-1973, 1974-1978, and 1979-1984 (Section 5.4). As is evident from Figure 8-4, the percent of meat and poultry samples in which HCB was detected increased significantly in 1974 and decreased significantly after 1978, producing a "hump" within the period 1974-1978. Since the dietary intake of HCB in meat and poultry (as well as dairy products) may account for the apparent peak in human adipose levels of HCB during the late 1970s, a rationale for this "hump" is relevant to the assessment of human exposure. From considerations to be given in the following discussion, it is hypothesized that ingestion by farm animals of feedstuffs contaminated with a higher than usual level of HCB was responsible for the increased level of HCB in meat and poultry samples during 1974-1978.

Inadvertent synthesis of HCB during the manufacture of several organic solvents produced in large volume appears to be the most significant production source of this compound, but essentially all of the HCB synthesized during solvent manufacture becomes part of the still bottoms, which are generally disposed of by landfilling or through incineration. Both of these practices curtail the entry of HCB into the environment, and thus widespread livestock contamination from this source should not be significant.

Hexachlorobenzene (HCB), however, has been introduced directly into the agricultural environment as a fungicide and as a contaminant of organochlorine insecticides and herbicides. The use of agricultural organochlorine compounds, in general, appears to have declined steadily over the period 1966-1982 (Table 8-1), and it can be assumed that the total release of HCB to the environment declined similarly. Although the persistence of HCB in soils has been noted (Section 4.5), this compound can be photolytically degraded in the presence of water (Section 4.2) and can also be transported in runoff water as an adsorbate on finely divided particulates (Section 4.5). Additionally, the moderately rapid rate of volatilization of this pollutant from water (Section 4.4) favors its widespread dissipation. For these reasons, an environmental accumulation of HCB, corresponding to the increased frequency of HCB detection in livestock within the period 1974-1978, should not have occurred. The increased frequency of HCB detection in livestock during this period, therefore, was probably associated with a specific route (or routes) of exposure rather than a general environmental build-up. In support of this contention, the ambient environmental level of HCB, as reflected in the downward trend of residue levels detected in starlings and fish during the period 1972-82, appears to be decreasing.

After 1978, detection of HCB in meat and poultry fat samples decreased markedly (see Figure 8-4). This decrease may be directly

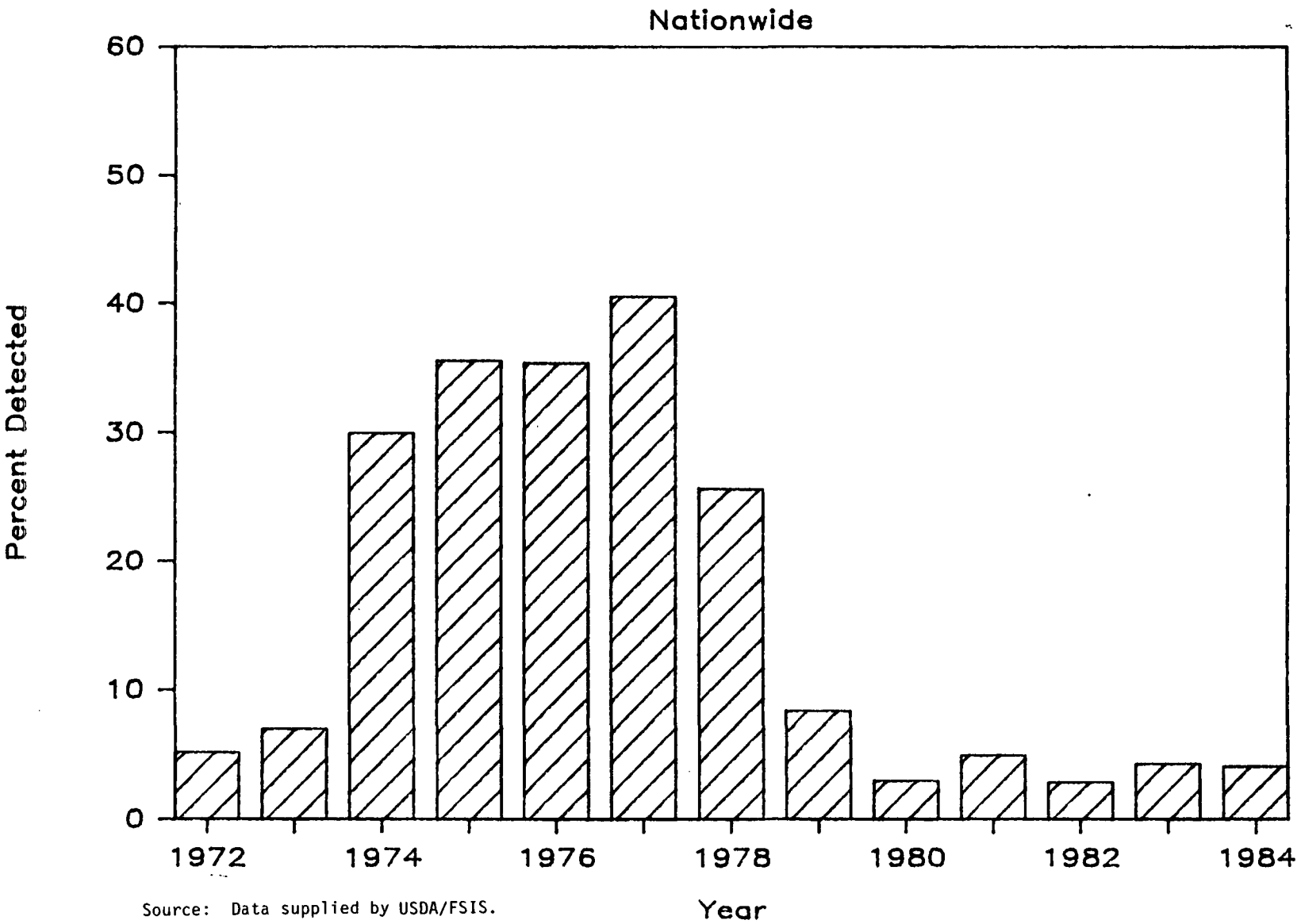
Table 8-1. Trends in Insecticide Use, 1966-1982[a]

Insecticide type	1966	1971	1976	1982
Organochlorines	82.8[b]	61.9	37.5	5.9
Organophosphates	36.6	65.0	64.2	≥42.2

[a] Eichers et al. (1978) and Eichers (1983) did not separate herbicide and fungicide use data into organochlorine and organophosphate categories

[b] All values are in millions of pounds.

Source: Eichers (1983), Eichers et al. (1978), USDA (1974), USDA (1970).



Source: Data supplied by USDA/FSIS.

Figure 8-4. HCB detection frequency in livestock.

related to restrictions placed on the agricultural use of organochlorine compounds that may contain HCB as a contaminant (e.g., aldrin, dieldrin, heptachlor) in the mid to late 1970s (USEPA 1985). Specific use(s) responsible for the increased HCB detection in meat and poultry may have been restricted at that time. Although HCB has apparently still been in limited use until recently for the prevention of wheat smut (Farm Chemicals Handbook 1986), it was not used widely on other grains or livestock feedstuffs.

The two routes of livestock exposure to HCB that would involve specific use(s) of organochlorine compounds are ingestion of food and dermal contact. Livestock feedstuffs could have become contaminated with HCB from heavy use of pesticides or herbicides during their growth or harvesting, and dermal exposure to pesticides could have occurred during the dipping and spraying of livestock. In this latter procedure, pesticides are applied directly to the skin of livestock for the control of insects and mite infestations. Specific contamination of ambient air and water that was being supplied to livestock, however, is difficult to envision.

8.2.2 Ingestion Exposure Route

Most farm animals in the United States are fed in feedlots, pens, or sheds before being prepared for slaughter (Van Arsdall and Nelson 1983, 1984; Gilliam 1984; Lasley 1983; Lasley et al. 1985). Prior to this time, grazing animals are allowed to feed on forage and pasture, although only a small percentage of this food source is treated with insecticides or herbicides (Table 8-2). Note, however, that 1976 use of pesticides on alfalfa was greater than use in 1971 and 1982.

The diet of cattle in a feedlot, according to the U.S. Department of Agriculture, consists of approximately one-third grain (mostly corn), one-half grain-crop silage, and about one-fifth hay (Van Arsdall and Nelson 1983). Monitoring data (Table 8-3) from the Food and Drug Administration (Surveillance and Compliance Summary Data for 1970-1976) indicate little or no contamination of these feedstuffs by HCB at levels above 10 ppb in 1974 and 1975. In 1976, however, HCB was detected in 23 percent of sampled feed grain and 25 percent of sampled hay; silage was reported as uncontaminated throughout the monitoring period.

Data from Eichers (1983), Eichers et al. (1978), and the USDA (1974) show that variations in the treatment of corn with organochlorine herbicides (Table 8-4) do not appear related to the periods of variation in HCB detection in meat and poultry (i.e., total organochlorine herbicides did not decrease from 1976 to 1982). (Herbicides are applied

Table 8-2. Pesticide Use on Forage and Pastures
(percent of acreage treated)

	1971	1976	1982
Insecticides			
Alfalfa	8	13	7
Hay	-	2	-
Pasture	-	-	-
Herbicides			
Alfalfa	1	3	1
Hay	1	2	3
Pasture	1	1	1

Sources: Eichers (1983), Eichers et al. (1978), USDA (1974).

Table 8-3. FDA Domestic Surveillance Summary Data

Animal feed commodity	1970	1971	1972	1973	1974	1975	1976	1970-1976
Number of samples								
Whole grain	89	82	226	265	145	68	31	906
Hay	138	82	24	17	-	50	37	348
Dehydrated hay	26	37	8	7	-	20	36	134
Animal byproducts	18	15	5	78	98	154	236	604
Fish byproducts	12	9	86	30	25	41	83	286
Misc. animal feed	139	119	537	118	37	109	98	1157
Fish byproducts (imported)	1	1	43	16	3	13	8	85
Percent positive samples								
Whole grain	0	0	0	1.13	0	0	22.58	1.10
Hay	0	1.22	0	0	-	8.00	16.22	3.16
Dehydrated hay	0	0	0	0	-	0	8.33	2.24
Animal byproducts	0	0	0	5.13	1.02	0.65	0.42	1.16
Fish byproducts	41.77	0	1.16	0	0	0	8.43	4.55
Misc. animal feed	0	0	0.37	2.54	0	2.75	2.04	0.60
Fish byproducts (imported)	0	0	0	0	0	0	0	0
Average concentration (ppb)								
Whole grain	0	0	0	1	0	0	14	0.9
Hay	0	0.9	0	0	-	1	2	0.6
Dehydrated hay	0	0	0	0	-	0	1	0.3
Animal byproducts	0	0	0	0.8	0.7	0.1	0.1	0.2
Fish byproducts	20	0	0.2	0	0	0	2	2
Misc. animal feed	0	0	< 0.1	0.4	0	3	0.9	0.4
Fish byproducts (imported)	0	0	0	0	0	0	0	0

Commodities in Which HCB Was Apparently Not Detected[a] (1970-1976)

Animal feeds	Number of samples
Oilseed byproducts	551
Ground grains	453
Vegetable byproducts	250
Silage	272

[a] Detection limit is 10 ppb.

Source: Duggan et al. (1983).

Table 8-4. Quantities of Herbicide Used on Corn
(10^6 pounds)

	1971	1976	1982
2,4-D	9.1	8.0	5.1
Atrazine	52.0	83.8	69.7
Cyanazine	-	10.4	20.7
Simazine	0.7	2.4	3.3
Total organochlorines	61.8	104.6	98.8
Total herbicides	101.1	207.1	243.4
% organochlorines	61	51	41

Acres of Corn Treated with Herbicides (10^6 acres treated)

	1971	1976	1982
2,4-D	16.6	12.5	11.3
Atrazine	36.0	56.9	47.9
Cyanazine	-	6.6	13.1
Simazine	-	1.8	3.3
Total organochlorines	52.6	77.8	75.6
Total acres planted		84.1	77.9
Percent treated		92.5	97.0

Source: Eichers (1983), Eichers et al. (1978), USDA (1974).

to corn acreage only before growth and maturation occur and should not contaminate mature portions of the corn plant.) Application rate of organochlorine insecticides to corn, (i.e., pounds of insecticide per acres of corn treated), however, appears to have been higher in 1976 than in 1971 and 1982 (Table 8-5); the increase in 1976 over 1971 is 17.5 percent. The use of heptachlor on corn increased 62 percent (based on pounds per acre) from 1971 to 1976, and the use of aldrin increased 73 percent. Although the use of chlordane and toxaphene decreased 12 percent and 75 percent, respectively (based on pounds per acre), the acreage treated by them is less than that treated by the former two insecticides. In addition, toxaphene is not recommended for use on post-emergent corn and perhaps should not be considered with the other three insecticides.

Most hay in the United States is produced from alfalfa (Van Arsdall and Nelson 1983). Organochlorine insecticide use on alfalfa increased from 1.04 pounds per acre to 2.4 pounds per acre between 1971 and 1976 (Table 8-6). This is an increase of 131 percent. Acreage of alfalfa also increased between these two years (Table 8-6) while the number of feedlot cattle was approximately the same (Van Arsdall and Nelson 1983). This increased usage of organochlorine insecticides on corn and alfalfa in 1976 compares well with the increased detection of HCB in sampled feed grain and hay reported by the FDA during the same year (see Table 8-3). Since corn and hay constitute almost one-half of the diet provided in a feedlot, this increased occurrence of HCB may have been the source of the increased HCB detected in meat produced from grazing animals.

Nongrazing farm animals (i.e., hogs and poultry) are currently fed a diet consisting primarily of feed grain (mostly corn) and soybean meal (Van Arsdall and Nelson 1984, Lasley et al. 1985). Although most hogs are now grown in total confinement, hog pastures may have contributed a large part to their diet during 1974-1978. Data given by Van Arsdall and Nelson (1984) show that approximately one-third of the hog farmers in the North-central region and one-half in the Southeast Region of the United States used pastures during their production program in 1980. Van Arsdall and Nelson (1984) further state that there were twice as many farms on which pastures were used for hog production in 1975 as there were in 1980. The pastureland most frequently used for hog production contained crop residues from legume (i.e., alfalfa, soybeans, and peanuts) or corn harvesting. Van Arsdall and Nelson (1984) point out, however, that the hogs rarely obtained their total diet from the pasture because they received a large portion of nourishment at feeding stations.

Based on the foregoing considerations, the two agricultural crops that contributed most to the diet of hogs were corn and legumes. The

Table 8-5. Quantities of Insecticide Used on Corn (10^6 pounds)

	1971	1976	1982
Heptachlor	1.1	1.6	-
Aldrin	7.8	0.9	-
Chlordane	0.8	1.4	-
Toxaphene	0.2	0.1	3.6[b]
Total organochlorines[a]	10.0	4.0	-
Total insecticides	25.5	32.0	27.4

Acres of Corn Treated with Insecticides (10^6 acres treated)

	1971	1976	1982
Heptachlor	1.9	1.7	-
Aldrin	7.5	0.5	-
Chlordane	0.5	1.0	-
Toxaphene	0.1	0.2	NA[b]
Total organochlorines[a]	10.3	3.5	-
Total acres planted		84.1	77.9
Percent acres treated[a]		4.2	-

[a] Excluding toxaphene.

[b] Toxaphene is not recommended for use on post-emergent corn used for silage.

Source: Eichers (1983), Eichers et al. (1978), USDA (1974).

Table 8-6. Insecticide Used on Alfalfa
(10^6 pounds)

	1971	1976	1982
Methoxychlor	0.5	1.4	-
Total organochlorines	0.5	1.4	-
Total insecticides	2.3	5.4	NA
Percent organochlorines	21.7	27.8	-
10^6 Acres treated	0.48	0.62	-

Source: Eichers (1983), Eichers et al. (1978), USDA (1974).

diet, however, has not been as controlled as the diet of cattle, and sources of contamination in the feedstuffs are more uncertain. This uncertainty is reflected in the decreased definitiveness between the periods of concern for detection of HCB residue levels in sampled hog meat (Figure 8-5).

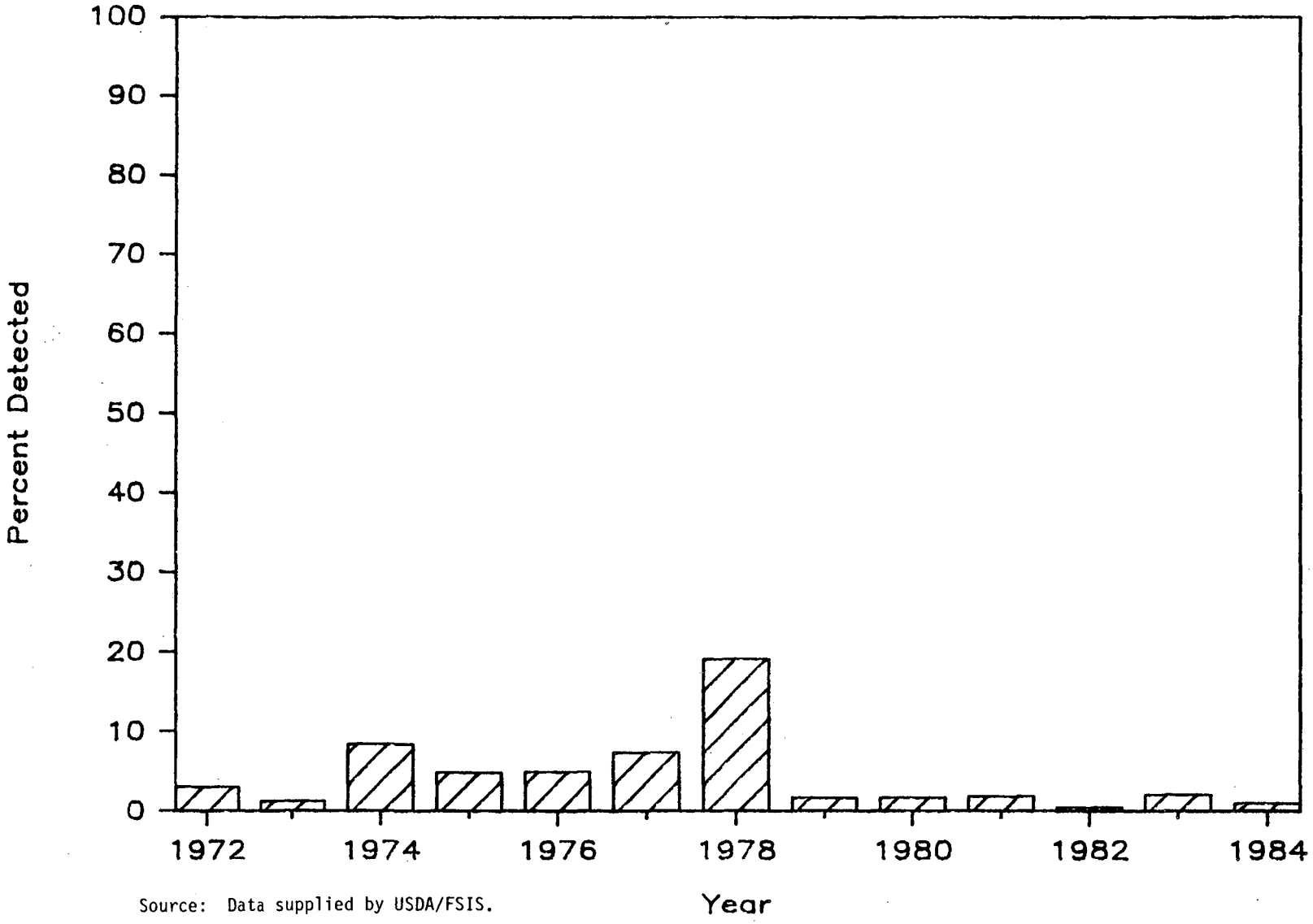
Possible contamination of feed corn with HCB from the use of organochlorine insecticides during the period 1974-1978 has been previously discussed. Contamination of processed soybeans and soybean meal by a similar route during the same period is less likely even though insecticide use on soybeans was substantially higher in 1978 than in 1971 and 1982 (Table 8-7). Corn allows penetration of insecticides into the husks and onto the ripening corn ears. In contrast, individual soybeans are protected by pods until the pods are removed in a processing facility. Therefore, although soybean meal is probably not an important source of HCB in the hog diet, but soybeans in a hog pasture could be a significant source.

Poultry in the United States is produced under confined conditions, and feedstuffs are purchased from commercial sources (Lasley 1983, Lasley et al. 1985). The feed grain used in poultry diets during 1974-1978 would have had the same sources of HCB contamination as the feed grain consumed by other farm animals. Soybean meal, as discussed, was probably not an important source of contamination, but protein supplements in the form of fish meal could have been a contributory source of HCB (see Table 8-3).

Figure 8-6 compares the occurrence of HCB detected in farm poultry to that detected in wild starlings during 1972-1982. It is evident that while HCB detection in the starlings had a downward trend throughout that period, detection of the contaminant in poultry increased to a peak in 1976, after which it dropped sharply. This difference in patterns is probably due to the effect of general environmental contamination of a natural avian diet versus the effect of contaminated feed grain in a commercial poultry diet.

8.2.3 Dermal Exposure Route

Besides ingestion of contaminated feedstuffs, dipping and spraying of livestock with organochlorine-containing formulations to combat pests is widespread, and it may also serve as a route for exposure to HCB. Table 8-8 gives the pesticides use for dipping or spraying of livestock for the years 1966, 1971, 1976, and 1982. The total amount of organochlorine insecticides used for this purpose was lower in 1976 compared to 1966 and 1971, although the amount of methoxychlor used had



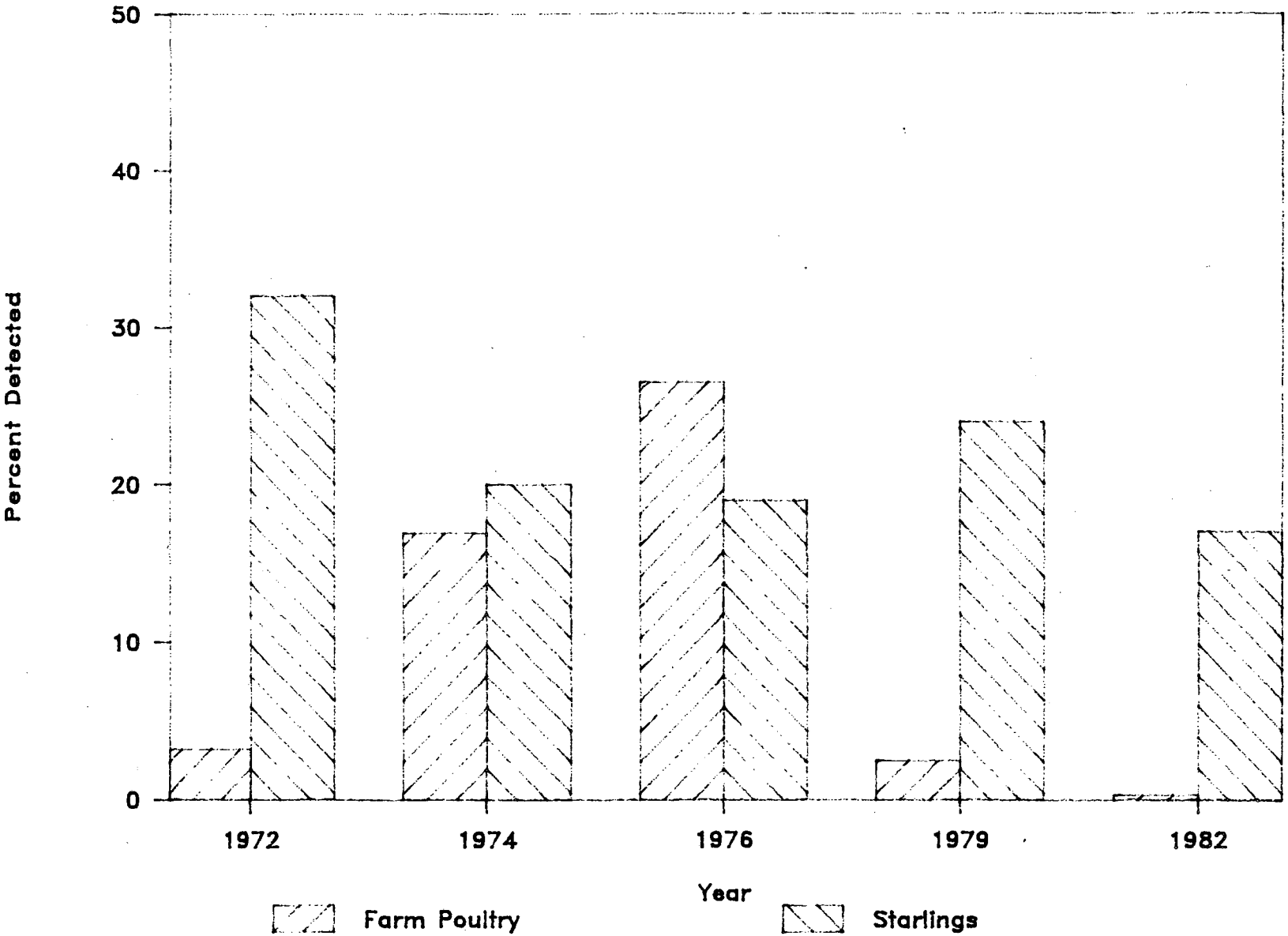
Source: Data supplied by USDA/FSIS.

Figure 8-5. HC[illegible]tected in swine, 1972-1984.

Table 8-7. Insecticide Used on Soybeans

	1971	1976	1982
Toxaphene (10^6 pounds)	1.5	2.2	3.7
10^6 Acres treated	0.95	0.49	1.9

Source: Eichers (1983), Eichers et al. (1978), USDA (1974).



Source: Data supplied by USDA/FSIS.

Figure 8-6. HCB dete in poultry vs. starlings.

Table 8-8. Insecticide Used on Livestock
(10^6 pounds - active ingredient)

	1966	1971	1976	1982
Organochlorines				
Lindane	0.3	0.4	0.2	[a]
DDT	0.5	0.2	-	-
Methoxychlor	1.5	2.0	2.4	[a]
Toxaphene	3.7	4.6	2.4	[b]
Other	0.2	0.4	-	NA
Total organochlorines	6.2	7.6	5.0	[a]
Organophosphates	3.1	5.4	1.6	[a]
Carbonates	0.5	1.2	3.6	[a]

[a] Used; quantity unknown.
[b] Used but restricted to scabies in beef cattle and sheep.

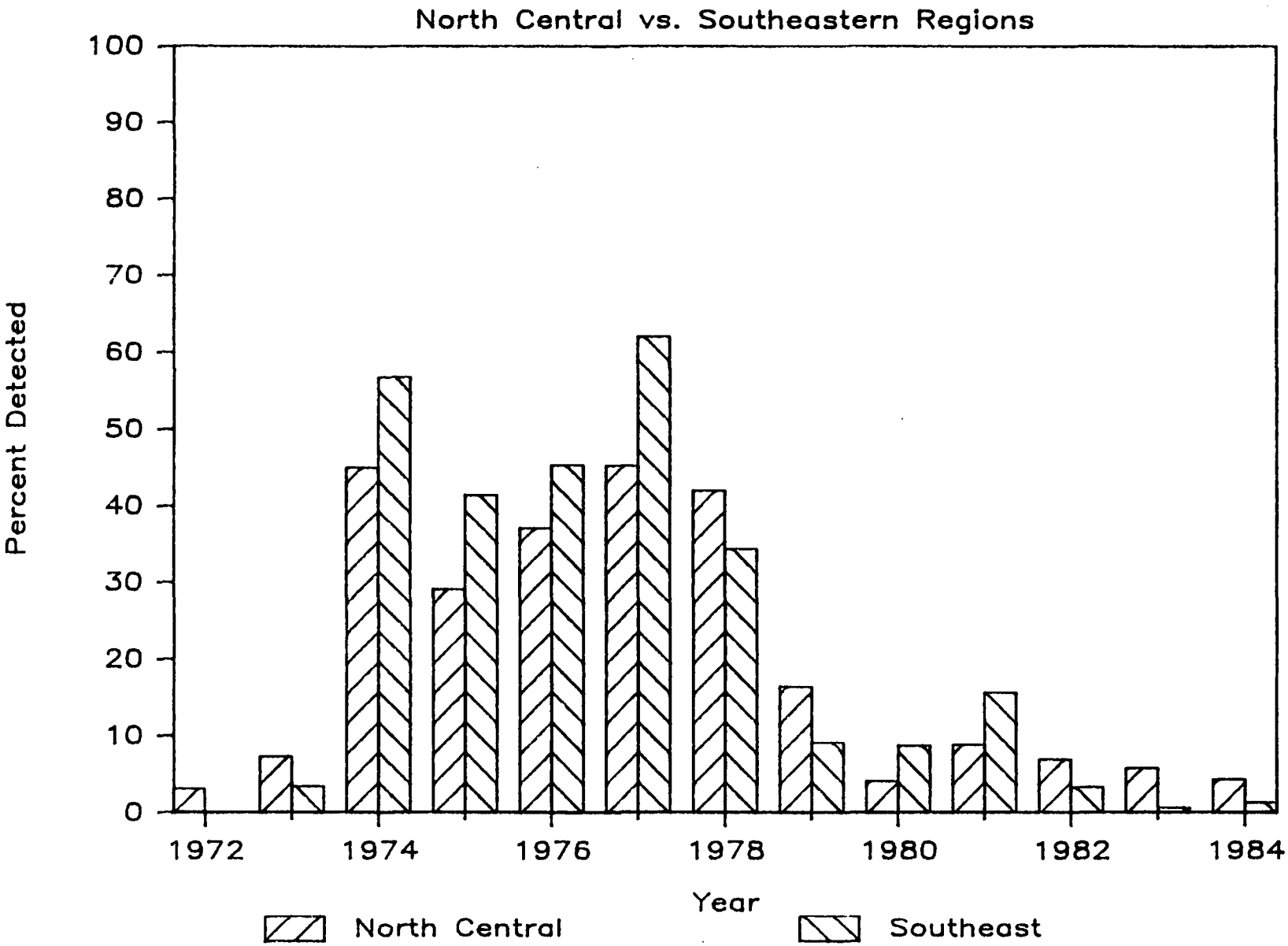
Source: Eichers (1983), Eichers et al. (1978), USDA (1974).

increased over this time period. Contamination of the livestock from dips and sprays could be expected to occur via ingestion and dermal absorption, but a comparison of data regarding the use of dipping and spraying equipment in the Southeastern and North-central regions of the United States (Gilliam 1984) with the USDA data for detection of HCB in meat from grazing animals (see Figure 5-20) in these two regions does not support this exposure route as an important one.

Between 1975 and 1980, the use of sprayers on cattle for external parasite control more than doubled in the Southeast and increased only slightly in the North Central region (Gilliam 1984). If the spraying of pesticide formulations were a major route for HCB exposure in cattle, the occurrence frequencies for HCB detection in meat from grazing animals in the two regions should have reflected this difference in the increased use of sprayers. Figure 8-7 shows a similar increase in the Southeast and North-central regions from 1975 to 1977 and an equivalent decrease in 1978. Although the foregoing comparison does not support dipping and spraying as an important route for HCB exposure, it, of course, cannot exclude it.

The argument that higher than usual contamination of livestock feedstuffs with HCB caused the USDA "hump" is based on a consideration of all available data. Some inconsistencies exist in the data, but they can probably be attributed to inconsistencies in sampling, since the studies from which the data were taken had not been designed for the purpose of testing the hypotheses presently being set forth. As an example, Table 8-3 (FDA Surveillance and Compliance Summary Data for 1970-1976) gives positive detection frequencies and concentrations of HCB in whole grain for agricultural feed but also indicates that HCB was undetected in silage. Most silage, as well as grain, that is fed to cattle is derived from corn grown on the farm where the cattle are being produced for slaughter. It is not known from the survey data whether corn or other feedstuffs that had not been purchased from commercial suppliers was included in the survey.

The source of the increased HCB in animal feedstuffs during 1974-1978 appears to be a greater than usual use of organochlorine pesticides on crops being grown for feedstuffs. Although total acreage treated with pesticides may not have seemed substantial, the higher concentrations of pesticide applied per acre could have resulted in a greater frequency of HCB detection. Reasons for this more frequent use of pesticides during the period of concern are not known but may have been prompted by pest infestations. Other possible sources of HCB to which livestock were exposed could not be assessed because data were not available. The effect that bioaccumulation of HCB and its clearance time in livestock have on the detection of HCB residue levels in meat and poultry was also not assessed.



Source: Data supplied by USDA/FSIS.

Figure 8-7. Comparison of HCB levels in cattle.

8.3 High Levels of HCB in Human Adipose Tissue Samples from the Pacific Census Division

8.3.1 Introduction

Leczynski and Stockrahm (1985) found that a large percentage of the specimens collected in the Pacific Census Division (38.1 percent) were above 0.09 ppm. The highest percentage for any other Census Division was 14.4 percent for the Middle Atlantic Division (see Figure 8-8). Although the NHATS Program is not designed for analysis at the state level, the unusually large percentage of upper residue level specimens found in the Pacific Census Division led Leczynski and Stockrahm (1985) to examine state data for this Division. The Washington and Oregon samples, which account for 16 and 22 percent, respectively, of the total Pacific Census Division Sample, had 61 percent and 42 percent, respectively, of their specimens above 0.09 ppm.

Data from other monitoring networks (Fish and Wildlife Service and USDA networks) were also compared to ascertain whether a similar trend exists (these data are summarized in Figures 8-9 to 8-11). In general, the detection frequency of HCB in the western regions was slightly higher than in other regions, although comparisons are difficult mostly because of different regional boundaries. The HCB detection frequency in duckwings was highest in the Pacific flyway for the last three sampling periods. The Western region had the highest occurrence of HCB in starlings in 1972, 1974, and 1982; however, in 1976 and 1979, the Western region's occurrence was similar to that of other regions. HCB was detected in freshwater fish in Oregon and Washington; however, it was more frequently detected near the Great Lakes and along the Ohio and Mississippi Rivers. The USDA for the Western Region had the highest HCB detection frequency in 1975 and 1976, but in other years, the Western Region was lower or very similar to other regions and overall regional differences were found not to be statistically significant (see Appendix C). Therefore, the other networks seem to generally correspond to the higher levels found in the NHATS data for the Pacific Census Region; although comparisons are difficult and the data trends are inconclusive.

8.3.2 Potential Sources

No conclusive information could be found to account for these higher levels of HCB in human adipose tissue in the Pacific Census Division (particularly Oregon and Washington) although there are several possible factors that could have contributed to this phenomenon: (1) the use of HCB as a pesticide in the region, (2) the use of pesticides that may

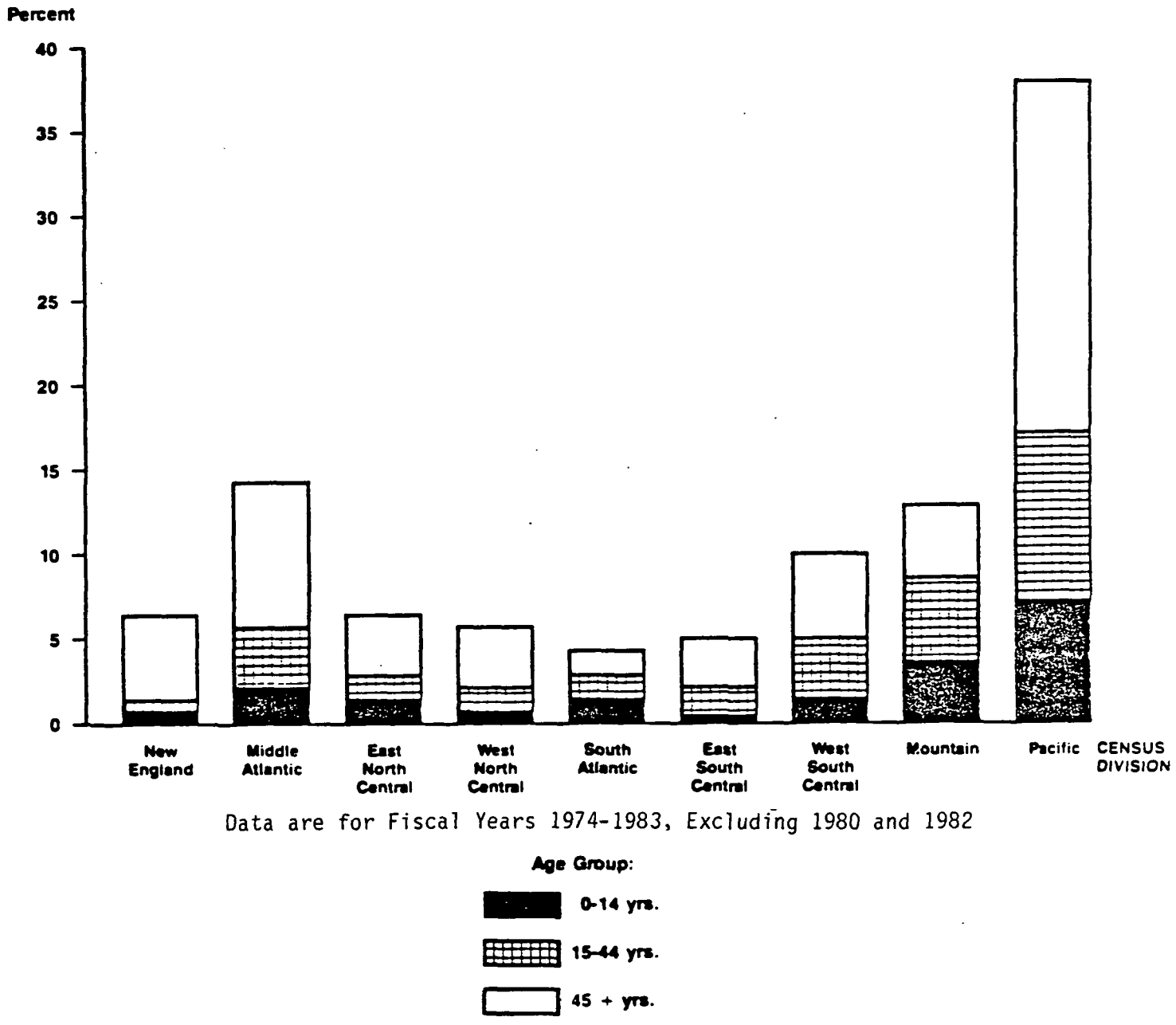


Figure 8-8. Percent of specimens above 0.09 ppm of HCB residue level by census division and age group.

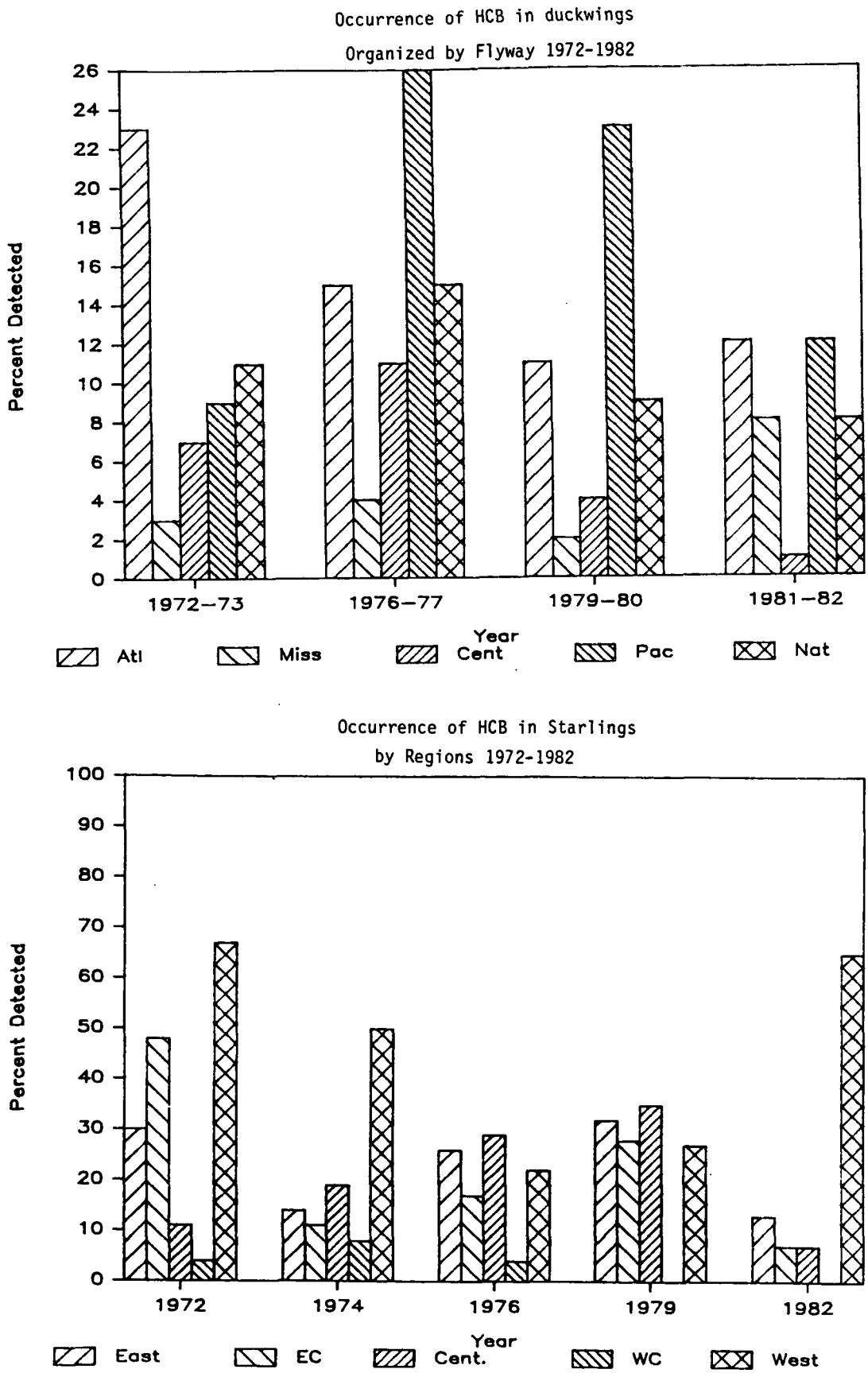


Figure 8-9. Detection frequency of HCB in ducks and starlings.

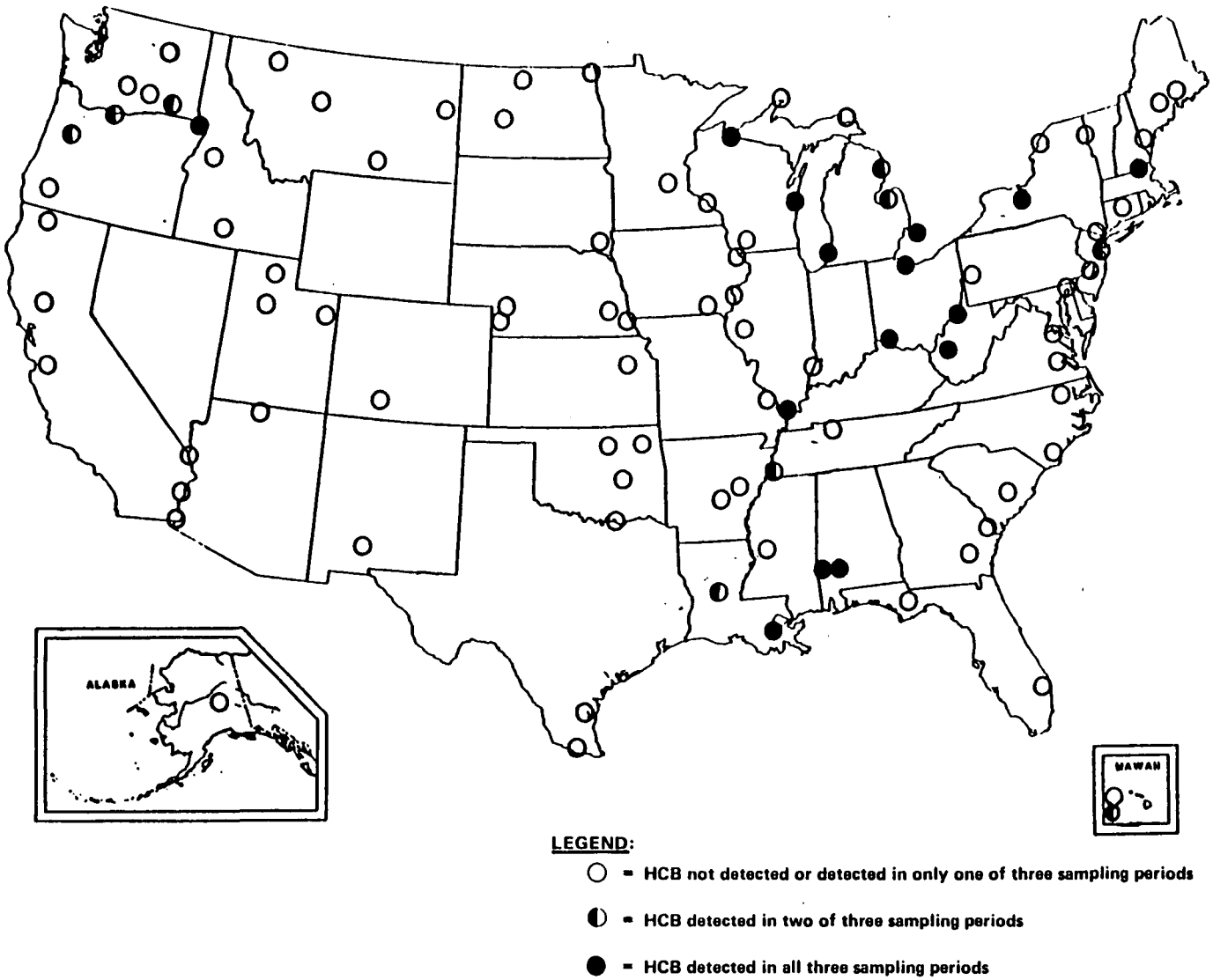


Figure 8-10. FWS national pesticide monitoring program: HCB residues in freshwater fish at 97 stations with consecutive data for the 1976-77, 1978-79, and 1980-81 surveys.

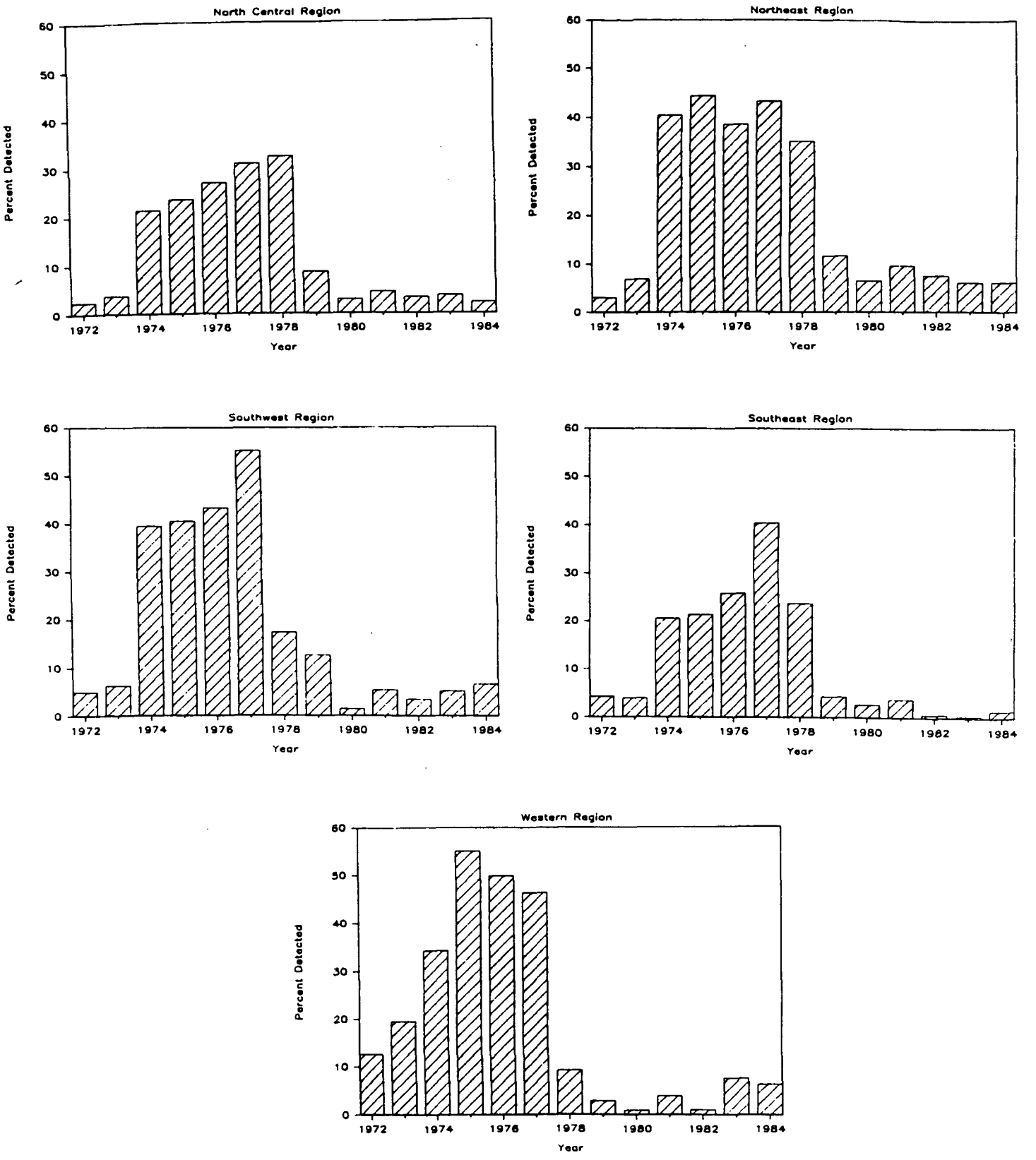


Figure 8-11. HCB detection frequency in domestic meat and poultry by USDA region (1972-1984).

contain HCB, (3) industrial sources, and (4) miscellaneous sources or factors (e.g., agricultural burning, poor air dispersion). Each of these potential sources is explained below.

(1) Direct Use of HCB as a Pesticide

Figure 8-12 shows the major geographic areas of HCB use. As can be seen, the heaviest use of HCB occurred in Oregon and Washington. It is probable that this increase use of HCB contributed to the higher levels of HCB in adipose tissue in the Northwest.

(2) The Use of Pesticides That May Contain HCB

HCB is known to be inadvertently produced during the manufacture of five pesticides. Three of these pesticides (dacthal, picloram, and pentachlorophenol) are used in widespread areas of the country; however, two of these pesticides (PCNB and chlorothalonil) are used in specific geographical areas (see Figures 8-13 and 8-14). As can be seen, both pesticides are used in Oregon and Washington, although they are used more extensively in other areas of the country, particularly the Southeast. If the use of these pesticides had a significant effect on adipose tissue levels, it should be reflected in the NHATS data for the Southeast, which was not the case. Therefore, the use of PCNB and chlorothalonil may have slightly contributed to the higher HCB levels in human adipose tissue samples from the Northwest, although it is doubtful that they were a significant source.

(3) Industrial Sources

Several current and historical industrial sources of HCB are located in the Northwest (see Figures 8-15 and 8-16); however, other areas of the country have even heavier concentrations of industrial sources, such as the Gulf Coast. This pattern is similar to that for the use of pesticides that may contain HCB, i.e., industrial sources are not expected to be a major contributor to the higher HCB levels in human adipose tissue samples from the Northwest.

(4) Miscellaneous Sources

Two additional factors that may contribute to the higher adipose tissue levels are (a) agricultural burning and (b) atmospheric stagnation. According to McAdams et al. (1985), the burning of grasses commonly occurs in Oregon, and, to a lesser extent, in Washington. In addition, it was reported that areas in Oregon that

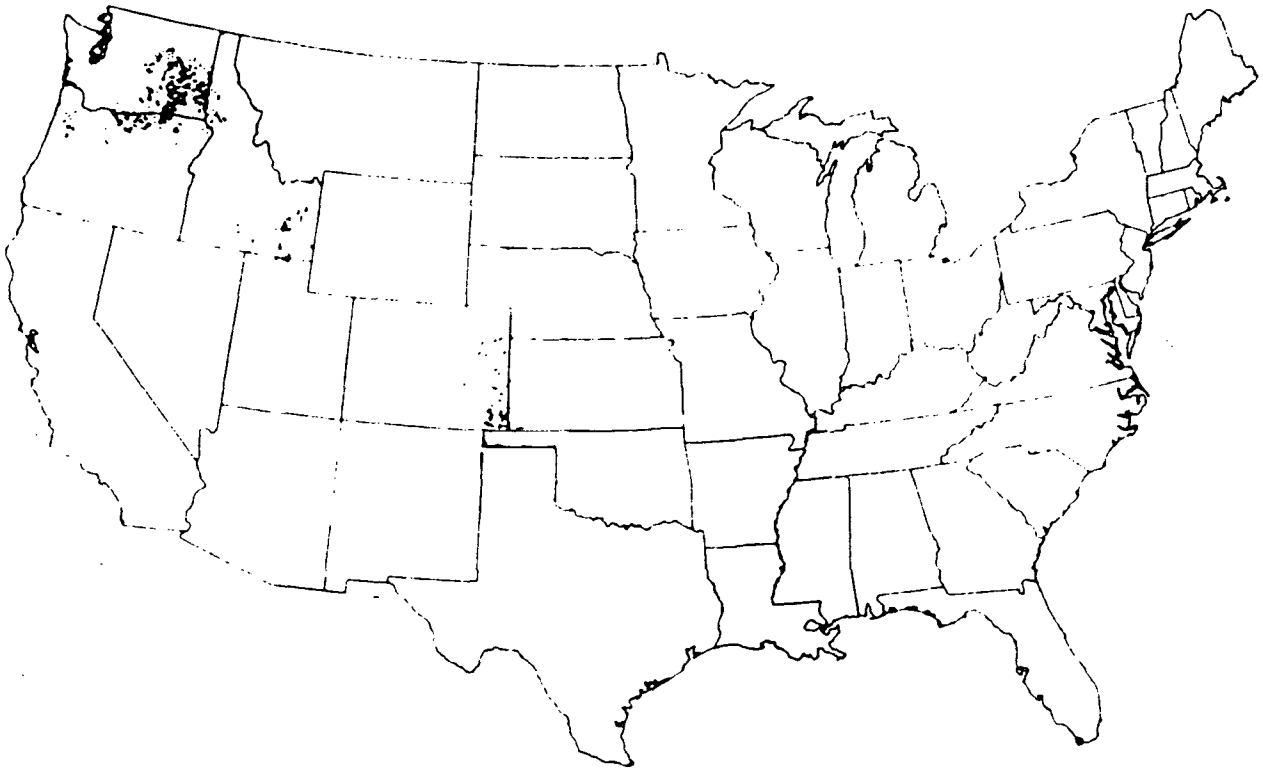


Figure 8-12. Major geographic areas of HCB use [Constructed by overlaying maps from the 1978 Census of Agriculture (U.S. Department of Commerce 1982) of "crop acreage harvested" for wheat in the Northwest U.S. and sorghum in Colorado. No maps available for onion acreage. Darkened areas of map indicate usage areas].

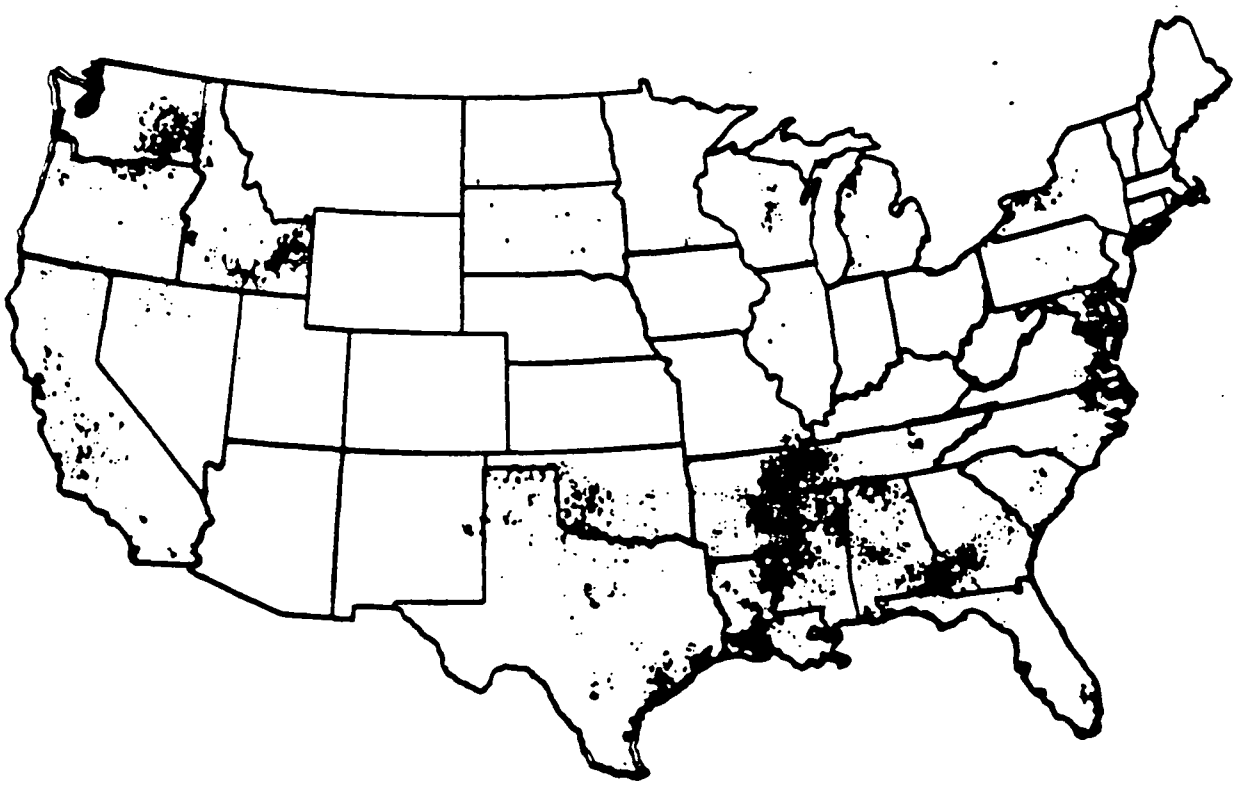


Figure 8-13. Major geographic areas of PCNB use [constructed by overlaying maps from the 1978 Census of Agriculture (U.S. Department of Commerce 1982) of "crop acreage harvested" for the following crops using the regional PCNB usage information in Table 3-2: barley, beans, cotten, oats, peanuts, potatoes, rice, soybeans, tomatoes, and wheat. Maps were not available for other crop uses. Darkened areas of map indicate usage areas].

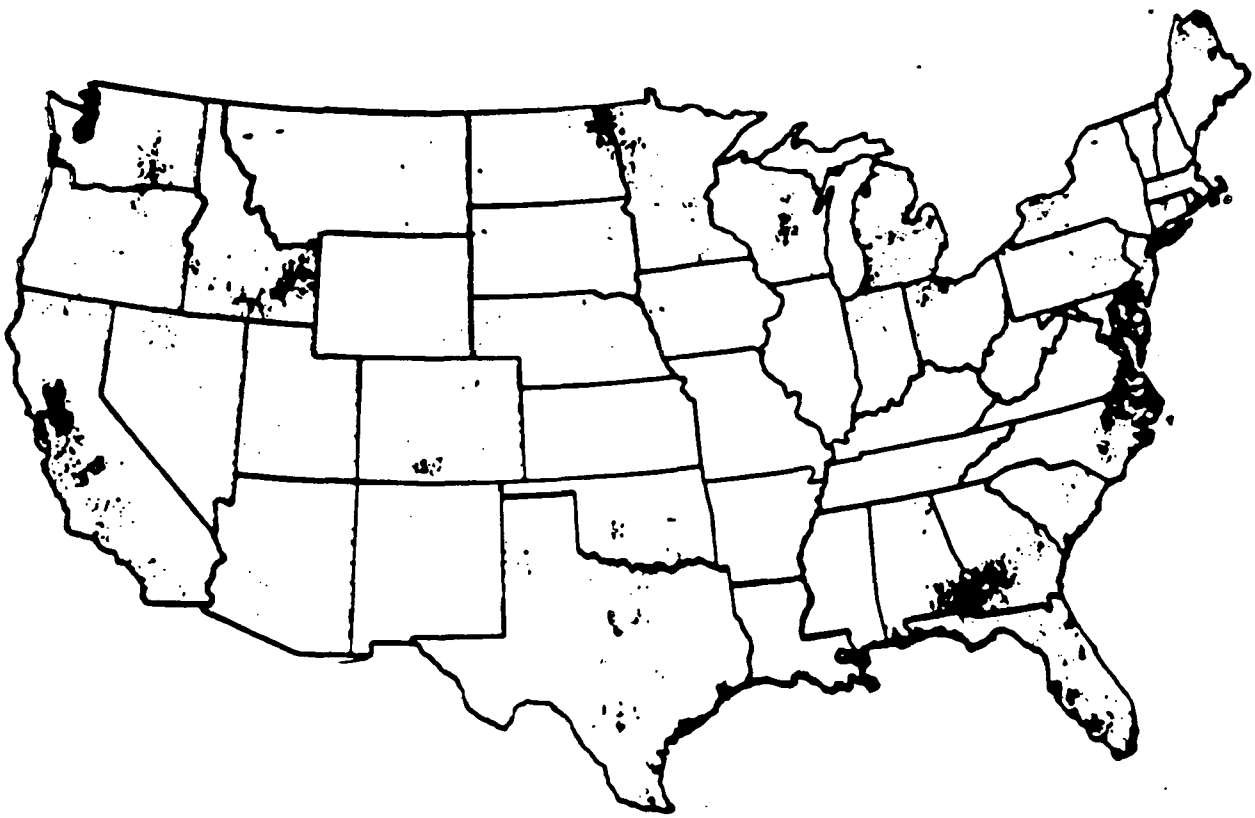
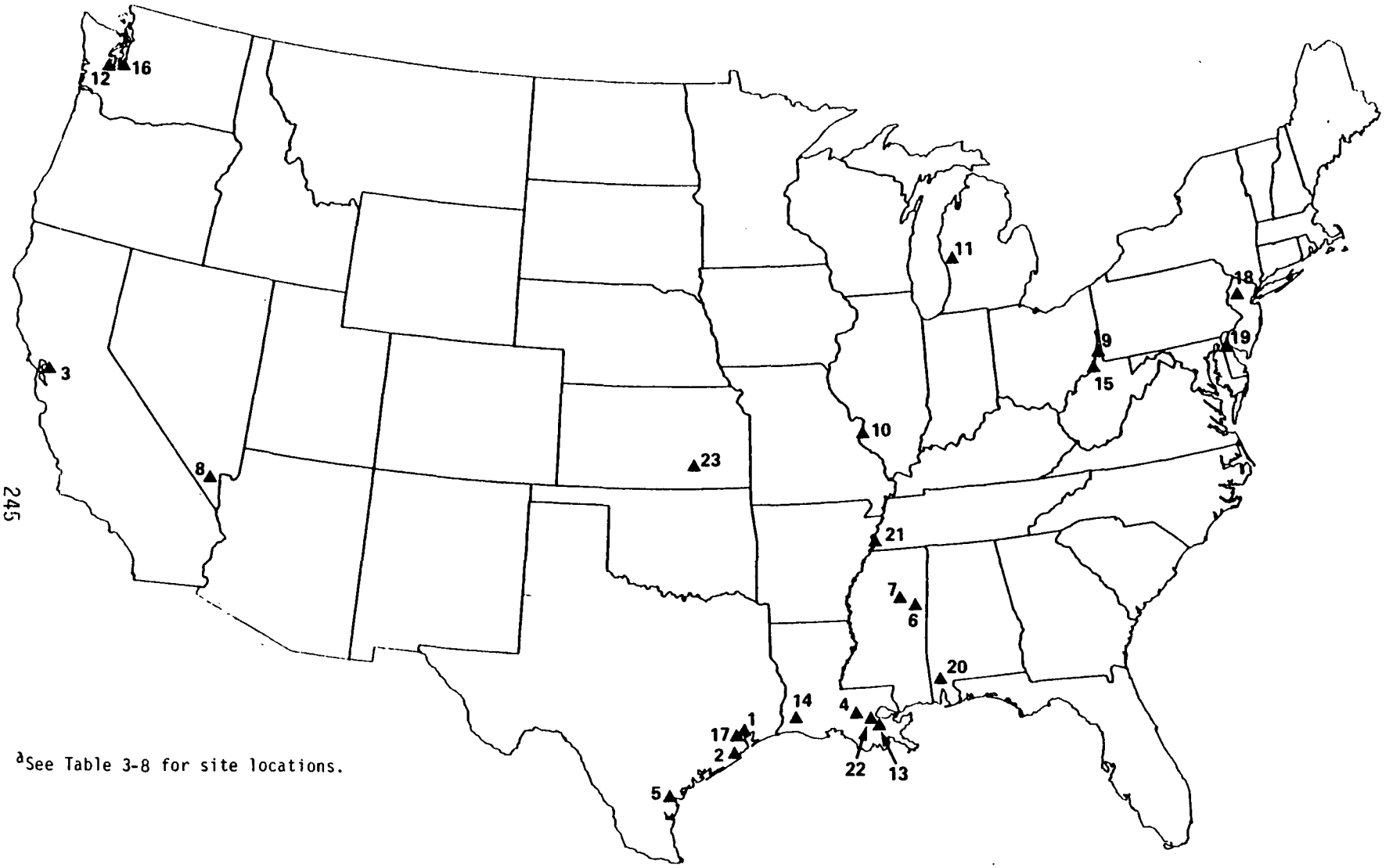
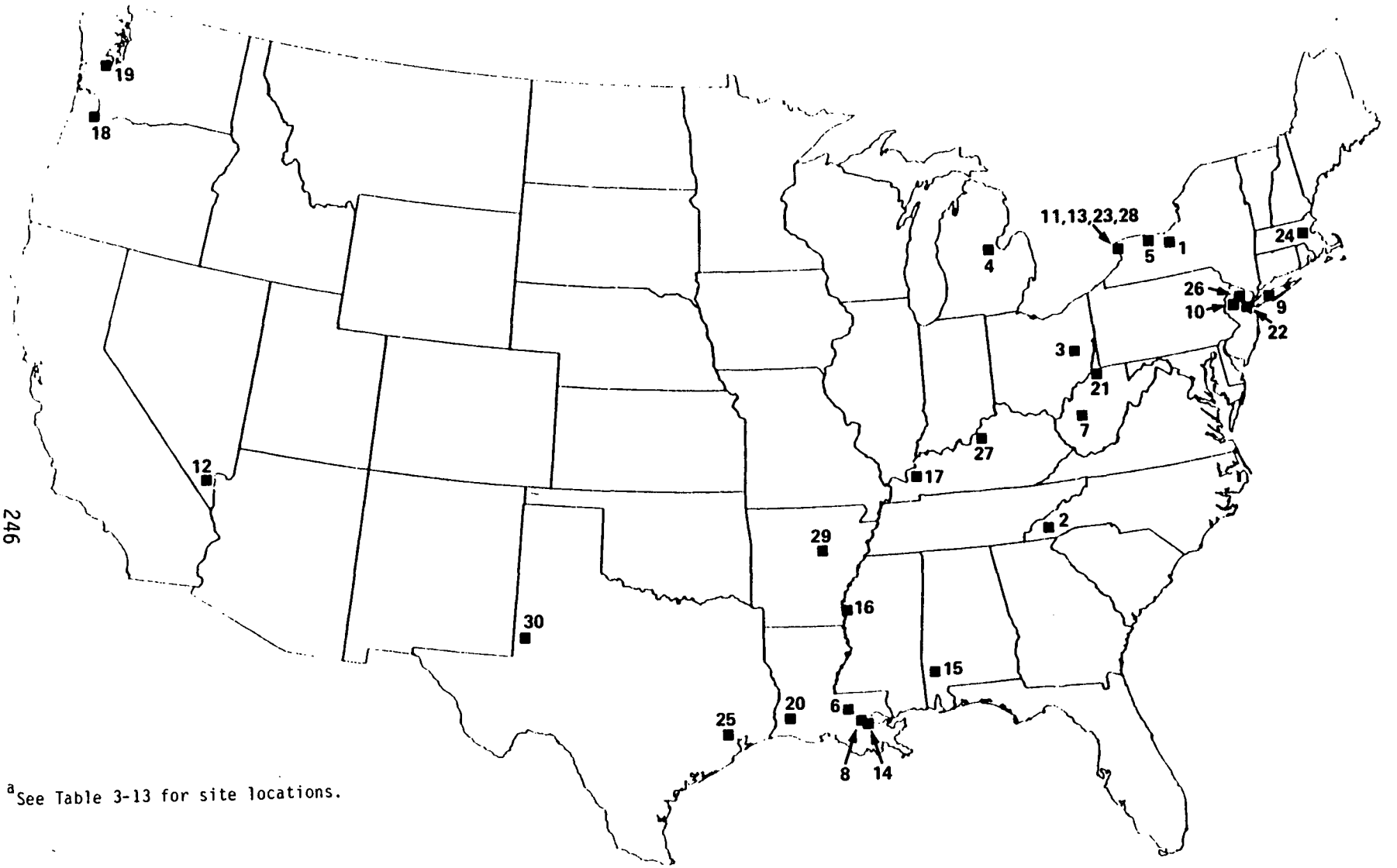


Figure 8-14. Major qeoqraphic areas of chlorothalonil use [constructed by overlaying maps from the 1978 Census of Agriculture (U.S. Department of Commerce 1982) of "crop acreage harvested" for the following crops using the regional chlorothalonil usage information in Table 3-4: cucumbers, peanuts, potatoes, and tomatoes. Maps were not available for other crop uses. Darkened areas of map indicate usage areasj.



[a]See Table 3-8 for site locations.

Figure 8-15. Locations of facilities currently producing chemicals whose manufacture is known to generate HCB[a].



[a]See Table 3-13 for site locations.

Figure 8-16. Locations of facilities that previously produced chemicals whose manufacture is known to generate HCB[a].

commonly burn grasses, such as the Willamette Valley, may exhibit poor atmospheric mixing. It is hypothesized that if the grasses or crops that are burned contain HCB, it could be easily transferred to the ambient air and then poorly dispersed because of the slow air mixing characteristics of the area. This theory is highly speculative because it is not known whether the burned grasses or crops contain HCB and because other geographic areas (e.g., California, Florida, Georgia, Hawaii, North Carolina, Arkansas, and along the coasts of Texas and Louisiana), which did not show high human adipose levels, also commonly burned grasses or agricultural crops. Consequently, it is doubtful that this explains the high tissue levels of HCB in the Northwest; ambient air monitoring data are needed to determine whether HCB levels in ambient air are higher in Oregon and Washington.

In summary, it appears that the use of HCB as a pesticide in the Northwest is probably the major contributor to the higher HCB levels in human adipose tissue samples from that area, although other factors may also contribute. More data are needed to draw definite conclusions.

8.4 Recommendations

Based on the information gathered for this exposure assessment, the following items are recommended:

- An expanded and more comprehensive source assessment, with additional data that better quantifies HCB releases to the various media. An assessment of historical sources of HCB, especially for past pesticidal uses, would also be useful.

- Field studies on transport of HCB may be necessary to determine the long-term environmental fate of HCB. Particular attention should be paid to monitoring the biota, water, and sediments of shorelines and estuaries.

- Temporal differences exist among USDA data, FDA data, and NHATS data. It would be useful, therefore, to have a "production to consumption" study of agricultural products undertaken for the purpose of resolving these temporal differences in monitoring.

- Pesticides suspected of containing HCB should be tested to see whether they do in fact contain HCB and at what levels. Particular emphasis should be placed on large volume pesticides that are used on foodstuffs and animal feedstuffs. Furthermore, additional testing of historical pesticide samples would be useful, particularly for defining the USDA "hump."

- Since large quantities of HCB are burned in industrial incinerators and HCB is known to be produced during combustion of organochlorine materials, gases and particulates from industrial incinerators should be monitored for HCB.

- More ambient monitoring data would be useful. We currently have no HCB monitoring data for ground water, and the data for HCB levels in ambient air and surface water are somewhat limited.

- Existing data on HCB in aquatic life indicate that bioconcentration and bioaccumulation may be sufficiently high in fish to consider restrictions on their use as food in specific geographic areas. Restrictions could be based on HCB monitoring in aquatic life from a specific fishing area. Further studies on HCB bioconcentration and bioaccumulation may be necessary.

8.5 References

Duggan RE, Corneliussen PE, Duggan MB, Memahom BM, Martin RJ. 1983 Pesticide residue levels in foods in the United States from July 1, 1969, to June 30, 1976. Washington, DC: U.S. Food and Drug Administration, Arlington, VA; Association of Ethical Analytical Chemicals.

Eichers T. 1983. Pesticides. Outlook and situation. Washington, DC: U.S. Department of Agriculture.
Eichers TR, Andrilenas PA, Anderso TW. 1978. Farmers' use of pesticides in 1976. Agric. Econ. Rep. No. 418. Washington, DC: U.S. Department of Agriculture.

Farm Chemicals Handbook. 1986. Farm chemicals handbook. Willoughby, OH: Meister Publishing Co.
Gilliam HC Jr. 1984. U.S. beef cow-calf industry. National Economics Division, Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 515 (NTIS GPO AER-15).

Lasley FA, Henson WL, Jones HB Jr. 1985. The U.S. turkey industry. National Economics Division, Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 525 (NTIS GPO AER-02).

Lasley FA. 1983. The U.S. poultry industry. National Economics Division Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 502 (NTIS GPO AER-02).

LecZynski BA, Stockrahm JW. 1985. An evaluation of hexachlorobenzene body burden levels in the general U.S. population. Draft report. Washington, DC: U.S. Environmental Protection Agency, Office of Toxic Substances. EPA Contract No. 68-01-6271.

McAdams MT, Meardon KR, Kent DP, Darley EF. 1984 Project summary, assessment for future environmental problems - agricultural residues. Washington, DC: Office of Research and Development, U.S. Environmental Protection Agency.

U.S. Department of Commerce. 1982. 1978 Census of Agriculture. Graphic Summary. Vol. 5, Part 1. Washington, DC: U.S. Department of Commerce, Bureau of the Census.

USDA. 1970. Quantities of pesticides used by farmers in 1966. Agric. Econ. Rep. No. 179. Washington, DC: U.S. Department of Agriculture.

USDA. 1974. Farmers' use of pesticides in 1971. Agric. Econ. Rep. No. 252. Washington, DC: U.S. Department of Agriculture.

USEPA. 1985. Suspended, cancelled and restricted pesticides. Washington, DC: Office of Pesticides and Toxic Substances (Compliance Monitoring Staff), USEPA,

Van Arsdall RN, Nelson KE. 1983. Characteristics of farmer cattle feeding. National Economics Division, Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 503 (NTIS GPO AER-03).

Van Arsdall RN, Nelson KE. 1984. U.S. hog production industry. National Economics Division, Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 511 (NTIS GPO AER-11).

APPENDIX A

HCB Detection Frequencies in FDA Surveillance Monitoring Program (Fiscal Years 1970 to 1984)

Table A-1. Summary of HCB Detection Frequency in FDA Domestic Surveillance Program (1970-76)[a]

Product code	Commodity group	Number of samples								Number of positive samples[a]								%Positive
		1970	1971	1972	1973	1974	1975	1976	1970-1976	1970	1971	1972	1973	1974	1975	1976	1970-1976	1970-1976
02A	Whole grains	?	?	?	?	?	?	?	1032	0	0	0	0	0	0	1	1	0.10
02B-Y	Milled grain products																	
03	Bakery products																	
04	Macaroni and noodle products																	
05	Cereal preparations																	
07	Snack food items																	
09A	Butter																	
09-C-Y	Milk and milk products	540	752	762	527	653	561	646	4441	1	18	17	37	26	36	9	144	3.25
12	Cheese and cheese products	161	154	67	108	89	93	86	758	2	3	7	0	2	2	0	16	2.11
13	Ice cream and related products																	
14	Imitation milk products																	
15	Egg and egg products	?	?	?	?	?	?	?	2445	?	0	0	?	?	?	?	15	0.61
16A-D	Fish and fish products	524	392	126	220	408	276	952	2898	7	1	1	13	49	9	80	160	5.52
16E-G	Shellfish	?	?	?	?	?	?	?	443	?	0	0	?	0	?	?	5	1.13
16J-L	Crustaceans																	
16M-Y	Other aquatic animals & products																	
18	Vegetable protein products																	
20-22	Fruits and fruit products	947	644	444	690	551	595	732	4603	0	1	0	6	9	0	1	17	0.37
23	Nuts and edible seeds	24	23	12	12	1	34	68	174	0	2	1	0	1	0	0	4	2.30
24A-E	Beans, vine, and ear vegetables	584	437	265	400	479	479	752	3396	2	0	0	4	1	3	7	17	0.50
24F-V	Leaf and stem vegetables	1298	1222	602	721	400	391	500	5134	25	23	11	5	3	2	1	70	1.36
25A-E	Mushrooms																	
25J-N	Root and tuber vegetables	567	549	249	335	289	641	548	3178	0	11	2	6	2	4	9	34	1.07
26	Vegetable oils																	
27	Dressings and condiments																	
28	Spices, flavors, and salts																	
29	Soft drinks and waters																	
30	Beverage bases, concentrates, and nectars																	
31	Coffee and tea																	
32	Alcoholic beverages																	
33	Candy without chocolate																	
34	Chocolate and cocoa products																	

Table A-1. (Continued)

Product code	Commodity group	Number of samples								Number of positive samples[a]								%Positive
		1970	1971	1972	1973	1974	1975	1976	1970–1976	1970	1971	1972	1973	1974	1975	1976	1970–1976	1970–1976
35	Gelatin, rennet, pudding, and pie mixes																	
36	Food sweeteners																	
37	Multiple food dinners, gravies, and sauces																	
38	Soups																	
40	Infant and junior food products	?	?	?	?	?	?	?	471	0	0	0	?	?	0	0	3	0.64
41	Dietary conventional foods																	
45–46	Food additives																	

[a]Detection limit is 0.01 ppm. Trace values were included as positive samples; trace levels were not analytically confirmed.
Source: Duggan et al. (1983).

Table A-2. Summary of HCB Detection Frequency in FDA Domestic Surveillance Program (1978-84)[a]

Product code	Commodity group	Number of samples								Number of positive samples[a]								%Positive
		1978	1979	1980	1981	1982	1983	1984	1978-1984	1978	1979	1980	1981	1982	1983	1984	1978-1984	1978-1984
02A	Whole grains	219	203	402	314	350	207	257	1952	0	5	1	1	4	0	0	11	0.56
02B-Y	Milled grain products	20	27	13	6	19	21	30	136	0	0	0	0	0	0	0	0	0
03	Bakery products	1	0	0	1	1	2	9	14	0	-	-	0	0	0	0	0	0
04	Macaroni and noodle products	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-
05	Cereal preparations	0	3	0	0	0	0	3	6	-	0	-	-	-	-	0	0	0
07	Snack food items	0	0	0	8	0	4	0	12	-	-	-	0	-	0	-	0	0
09A	Butter	29	9	16	23	25	27	16	145	0	0	0	0	15	2	3	20	13.79
09C-Y	Milk and milk products	519	499	416	435	402	498	396	3165	23	15	4	18	22	8	5	95	3.00
12	Cheese and cheese products	95	45	133	131	144	119	97	764	7	0	1	13	10	7	0	38	4.97
13	Ice cream and related products	0	2	3	9	9	28	20	71	-	0	0	0	0	0	0	0	0
14	Imitation milk products	2	0	4	9	1	1	2	19	0	-	0	0	0	0	0	0	0
15	Egg and egg products	298	266	491	439	318	408	387	2607	0	2	2	0	1	2	1	8	0.31
16A-D	Fish and fish products	729	512	598	502	272	347	197	3157	80	69	161	97	97	64	13	581	18.40
16E-G	Shellfish	45	42	37	61	84	69	26	364	3	0	1	0	0	0	0	4	1.10
16J-L	Crustaceans	38	46	104	70	47	35	18	358	2	0	1	0	0	0	0	3	0.84
16M-Y	Other aquatic animals & products	5	10	4	4	1	11	3	38	0	0	0	0	0	0	0	0	0
18	Vegetable protein products	0	0	0	0	0	1	0	1	-	-	-	-	-	0	-	0	0
20-22	Fruits and fruit products	856	955	1096	1155	1069	1107	1582	7820	7	2	9	4	12	0	0	34	0.43
23	Nuts and edible seeds	95	120	96	141	144	163	147	906	13	12	9	0	0	3	5	42	4.64
24A-I	Beans, vines, and ear vegetables	911	881	1086	854	1124	921	1032	6809	5	8	10	15	7	5	0	50	0.73
24J-V	Leaf and stem vegetables	654	664	1043	1013	1004	1472	1538	7388	6	5	0	6	0	1	1	19	0.26
25A-I	Mushrooms	12	16	43	24	31	32	24	182	0	1	2	0	0	0	0	3	1.65
25J-N	Root and tuber vegetables	579	516	639	499	578	698	585	4094	3	4	10	2	2	5	3	29	0.71
26	Vegetable oils	10	12	9	46	22	34	22	155	0	0	0	0	0	0	0	0	0
27	Dressings and condiments	0	0	0	0	0	3	0	3	-	-	-	-	-	0	-	0	0
28	Spices, flavors, and salts	2	16	4	30	15	15	35	117	0	0	0	0	0	0	0	0	0
29	Soft drinks and waters	1	1	1	4	10	2	5	24	0	0	0	0	0	0	0	0	0
30	Beverage bases, concentrates, and nectars	0	1	0	1	0	0	0	2	-	0	-	0	-	-	-	0	0
31	Coffee and tea	1	1	5	0	3	2	0	12	0	0	0	-	0	0	-	0	0
32	Alcoholic beverages	0	0	16	0	0	10	4	30	-	-	0	-	-	0	0	0	0
33	Candy without chocolate	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-
34	Chocolate and cocoa products	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-

Table A-2. (Continued)

Product code	Commodity group	Number of samples								Number of positive samples[a]								%Positive
		1978	1979	1980	1981	1982	1983	1984	1978–1984	1978	1979	1980	1981	1982	1983	1984	1978–1984	1978–1984
35	Gelatin, rennet, pudding, and pie mixes	0	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–	–
36	Food sweeteners	12	5	2	8	4	8	12	51	0	0	0	0	0	0	0	0	0
37	Multiple food dinners, gravies, and sauces	0	0	2	5	3	9	2	21	–	–	0	0	0	0	0	0	0
38	Soups	0	0	0	0	0	0	3	3	–	–	–	–	–	–	0	0	0
40	Infant and junior food products	0	0	0	1	10	6	1	18	–	–	–	0	0	0	0	0	0
41	Dietary conventional foods	0	0	1	0	0	1	0	2	–	–	0	–	–	0	–	0	0
45–46	Food additives	0	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–	–

[a]Data supplied by FDA Center for Food Safety and Applied Nutrition.
[b]Detection limit is 0.01 ppm. Trace values were included as positive samples; trace levels were not analytically confirmed.

Table A-3. Summary of HCB Detection Frequency in FDA Import Surveillance Program (1978-84)[a]

Product code	Commodity group	Number of samples								Number of positive samples[a]								%Positive
		1978	1979	1980	1981	1982	1983	1984	1978-1984	1978	1979	1980	1981	1982	1983	1984	1978-1984	1978-1984
02A	Whole grains	11	4	5	3	9	2	8	42	1	0	0	0	1	0	0	2	4.76
02B-Y	Milled grain products	8	15	11	5	4	9	24	76	0	0	0	0	0	0	0	0	0
03	Bakery products	3	0	0	2	0	0	1	6	0	-	-	0	-	-	0	0	0
04	Macaroni and noodle products	10	18	42	2	2	1	3	78	2	4	3	0	0	0	0	9	11.54
05	Cereal preparations	1	2	2	0	0	0	3	8	0	0	0	-	-	-	0	0	0
07	Snack food items	0	0	0	0	1	1	1	3	-	-	-	-	0	0	0	0	0
09A	Butter	0	0	2	2	1	0	3	8	-	-	1	0	1	-	0	2	25.00
09C-Y	Milk and milk products	1	4	5	5	23	10	3	51	0	0	1	0	1	0	0	2	3.92
12	Cheese and cheese products	131	101	74	34	33	32	38	443	40	10	19	4	9	5	0	87	19.64
13	Ice cream and related products	0	0	1	0	0	0	1	2	-	-	0	-	-	-	0	0	0
14	Imitation milk products	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-
15	Egg and egg products	48	61	45	8	11	15	76	264	0	1	0	0	0	0	0	1	0.38
16A-D	Fish and fish products	244	207	243	97	53	60	47	951	18	21	21	7	5	6	4	82	8.62
16E-G	Shellfish	20	5	20	13	3	0	4	65	2	0	0	0	0	-	0	2	3.08
16J-L	Crustaceans	53	18	14	1	3	1	0	90	3	0	0	0	0	0	-	3	3.33
16M-Y	Other aquatic animals & products	12	5	8	3	3	1	5	37	0	0	2	1	0	0	0	3	8.11
18	Vegetable protein products	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-
20-22	Fruit and fruit products	144	411	507	441	384	851	991	3729	0	0	0	0	1	0	1	2	0.05
23	Nuts and edible seeds	1	47	18	130	9	24	35	264	0	2	1	0	0	1	0	4	1.52
24A-C	Beans, vine, and ear vegetables	918	1035	1196	1496	1544	2359	2205	10,753	1	4	1	3	6	1	3	20	0.18
24D-V	Leaf and stem vegetables	80	133	136	117	198	213	272	1172	0	0	0	0	0	0	0	0	0
25A-C	Mushrooms	24	29	35	6	2	2	4	102	1	2	1	0	0	0	0	4	3.92
25D-H	Root and tuber vegetables	97	105	161	94	101	98	133	789	1	9	10	2	2	1	5	30	3.80
26	Vegetable oils	5	0	3	4	7	2	2	23	0	-	0	0	0	0	0	0	0
27	Dressings and condiments	0	1	1	0	1	0	0	3	-	0	0	-	0	-	-	0	0
28	Spices, flavors, and salts	12	33	23	33	64	69	50	284	0	2	0	3	1	2	0	8	2.82
29	Soft drinks and waters	0	0	2	1	2	0	0	5	-	-	0	0	0	-	-	0	0
30	Beverage bases, concentrates, and nectars	1	2	2	2	0	0	1	8	0	0	0	0	-	-	0	0	0
31	Coffee and tea	23	10	8	11	4	8	14	78	0	0	0	0	0	0	0	0	0
32	Alcoholic beverages	1	0	3	1	0	1	1	7	0	-	0	0	-	0	0	0	0
33	Candy without chocolate	0	4	0	1	0	0	1	6	-	0	-	0	-	-	0	0	0
34	Chocolate and cocoa products	6	2	0	1	2	1	1	13	1	0	-	0	0	0	0	1	7.69

Table A-3. (Continued)

Product code	Commodity group	Number of samples								Number of positive samples[a]								%Positive
		1978	1979	1980	1981	1982	1983	1984	1978–1984	1978	1979	1980	1981	1982	1983	1984	1978–1984	1978–1984
35	Gelatin, rennet, pudding, and pie mixes	1	1	0	0	0	0	1	3	0	0	–	–	–	–	0	0	0
36	Food sweeteners	3	2	3	2	0	1	8	19	0	0	0	0	–	0	0	0	0
37	Multiple food dinners, gravies, and sauces	2	3	0	1	0	2	0	8	0	0	–	0	–	0	–	0	0
38	Soups	5	1	3	0	0	0	0	9	0	0	0	–	–	–	–	0	0
40	Infant and junior food products	0	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–	–
41	Dietary conventional foods	0	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–	–
45–46	Food additives	0	0	3	2	0	0	0	5	–	–	0	0	–	–	–	0	0

[a]Data supplied by FDA Center for Food Safety and Applied Nutrition.
[b]Detection limit is 0.01 ppm. Trace values were included as positive samples; trace levels were not analytically confirmed.

Appendix B

HCB Detection Frequencies in Domestic Meat and Poultry Fat Samples (Tabular Data by "Species" and Year - 1972 to 1984)

Notes for Tables B-1 through B-13

[a]Data collected through the National Residue Monitoring Program of the USDA Food Safety Inspection Service.

[b]Residues reported on a wet weight basis.

[c]Limit of detection is 0.01 ppm.

[d]Includes residues reported for lambs and mature sheep.

[e]Includes residues reported for hogs, boars, and sows.

Table B-1. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1972)

Species	Sample size	Concentration interval (ppm)[b] Not detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	2	2	0	0	0	0.0
Steers	112	103	8	1	0	8.0
Cows	36	31	4	0	1	14
Heifers	52	51	1	0	0	1.9
Calves	11	11	0	0	0	0.0
Sheep[d]	131	114	16	0	1	13
Goats	0	--	--	--	--	--
Swine[e]	130	126	2	2	0	3.1
Horses	0	--	--	--	--	--
Young chickens	126	118	8	0	0	6.3
Mature chickens	234	229	5	0	0	2.1
F/R turkeys	86	84	2	0	0	2.3
Young turkeys	121	118	2	1	0	2.5
Mature turkeys	0	--	--	--	--	--
Ducks	0	--	--	--	--	--
Geese	0	--	--	--	--	--
Rabbits	0	--	--	--	--	--
TOTAL	1,041	987	48	4	2	5.2

Table B-2. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1973)

Species	Sample size	Concentration interval (ppm)[b] Not detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	7	5	2	0	0	28.6
Steers	118	108	8	1	1	8.5
Cows	528	488	34	6	0	7.6
Heifers	57	56	1	0	0	1.8
Calves	84	55	29	0	0	34.5
Sheep[d]	249	206	35	6	2	17.3
Goats	40	32	8	0	0	20
Swine[e]	232	229	2	1	0	1.3
Horses	44	44	0	0	0	0.0
Young chickens	135	129	5	1	0	4.4
Mature chickens	395	392	2	1	0	0.8
F/R turkeys	114	112	2	0	0	1.8
Young turkeys	360	345	15	0	0	4.2
Mature turkeys	43	31	12	0	0	27.9
Ducks	75	75	0	0	0	0.0
Geese	20	20	0	0	0	0.0
Rabbits	0	-	-	-	-	-
TOTAL	2,501	2,327	155	16	3	7.0

Table B-3. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1974)

Species	Sample size	Concentration interval (ppm)[b] Not detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	61	22	39	0	0	63.9
Steers	223	181	42	0	0	18.8
Cows	587	285	300	2	0	51.4
Heifers	124	100	24	0	0	19.4
Calves	282	68	213	1	0	75.9
Sheep[d]	267	133	126	8	0	50.2
Goats	104	33	70	0	1	68.3
Swine[e]	327	299	27	1	0	8.6
Horses	265	176	89	0	0	33.6
Young chickens	467	373	94	0	0	20.1
Mature chickens	566	488	78	0	0	13.8
F/R turkeys	248	193	55	0	0	22.2
Young turkeys	475	404	71	0	0	14.9
Mature turkeys	9	8	1	0	0	11.1
Ducks	100	100	0	0	0	0.0
Geese	48	42	6	0	0	12.5
Rabbits	19	15	4	0	0	21.1
TOTAL	4,172	2,920	1,239	12	1	30.0

Table B-4. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1975)

Species	Sample size	Concentration interval (ppm)[b] Not detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	113	45	67	1	0	60.2
Steers	519	414	105	0	0	20.2
Cows	771	369	399	3	0	52.1
Heifers	330	258	72	0	0	21.8
Calves	269	97	171	1	0	63.9
Sheep[d]	292	145	143	4	0	50.3
Goats	64	24	40	0	0	62.5
Swine[e]	324	308	15	1	0	4.9
Horses	261	64	191	5	1	75.4
Young chickens	362	269	93	0	0	25.7
Mature chickens	415	342	73	0	0	17.6
F/R turkeys	209	117	92	0	0	44.0
Young turkeys	250	157	93	0	0	37.2
Mature turkeys	95	66	29	0	0	30.5
Ducks	235	214	21	0	0	8.9
Geese	11	11	0	0	0	0.0
Rabbits	71	58	13	0	0	18.3
TOTAL	4,591	2,958	1,618	14	1	35.6

Table B-5 Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1976)

Species	Sample size	Concentration interval (ppm)[b] Not detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	110	43	65	2	0	60.9
Steers	231	169	62	0	0	26.8
Cows	1,244	715	527	2	0	42.5
Heifers	200	138	61	0	1	31.0
Calves	327	117	207	3	0	64.2
Sheep[d]	206	105	101	0	0	49.0
Goats	44	10	34	0	0	77.3
Swine[e]	442	420	22	0	0	5.0
Horses	217	39	177	1	0	82.0
Young chickens	381	300	81	0	0	21.3
Mature chickens	546	459	87	0	0	15.9
F/R turkeys	116	57	59	0	0	50.9
Young turkeys	227	126	101	0	0	44.5
Mature turkeys	113	74	39	0	0	34.5
Ducks	246	223	22	1	0	9.3
Geese	21	20	1	0	0	4.8
Rabbits	65	44	21	0	0	32.3
TOTAL	4,736	3,059	1,667	9	1	35.4

Table B-6. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1977)

Species	Sample size	Concentration interval (ppm)[b] Not detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	32	8	24	0	0	75.0
Steers	91	65	26	0	0	28.6
Cows	656	288	365	3	0	56.1
Heifers	101	67	34	0	0	33.7
Calves	124	40	84	0	0	67.7
Sheep[d]	75	31	44	0	0	58.7
Goats	25	5	20	0	0	80.0
Swine[e]	215	199	15	1	0	7.4
Horses	112	20	92	0	0	82.1
Young chickens	86	70	16	0	0	18.6
Mature chickens	289	210	79	0	0	27.3
F/R turkeys	60	30	30	0	0	50.0
Young turkeys	156	104	52	0	0	33.3
Mature turkeys	87	58	29	0	0	33.3
Ducks	176	168	8	0	0	4.5
Geese	10	9	1	0	0	10.0
Rabbits	21	3	18	0	0	85.7
TOTAL	2,316	1,375	937	4	0	40.6

Table B-7. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1978)

Species	Sample size	Concentration interval (ppm)[b] Not detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	30	22	8	0	0	26.7
Steers	79	62	17	0	0	21.5
Cows	781	526	255	0	0	32.7
Heifers	85	61	24	0	0	28.2
Calves	207	125	82	0	0	39.6
Sheep[d]	81	59	22	0	0	27.2
Goats	10	6	4	0	0	40.0
Swine[e]	415	335	76	3	1	19.3
Horses	73	47	25	1	0	35.6
Young chickens	208	181	27	0	0	13.0
Mature chickens	164	143	21	0	0	12.8
F/R turkeys	50	37	13	0	0	26.0
Young turkeys	132	106	26	0	0	19.7
Mature turkeys	21	11	10	0	0	47.6
Ducks	77	67	10	0	0	13.0
Geese	10	10	0	0	0	0.0
Rabbits	29	23	6	0	0	20.7
TOTAL	2,452	1,821	626	4	1	25.7

Table B-8. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1979)

Species	Sample size	Concentration interval (ppm)[b] Not Detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	69	57	12	0	0	17.4
Steers	114	107	5	2	0	6.1
Cows	962	850	110	2	0	11.6
Heifers	113	106	6	1	0	6.2
Calves	575	455	119	1	0	20.9
Sheep[d]	171	144	27	0	0	15.8
Goats	91	83	7	1	0	8.8
Swine[e]	1,305	1,282	20	2	1	1.8
Horses	191	145	43	3	0	24.1
Young chickens	235	228	7	0	0	3.0
Mature chickens	247	244	3	0	0	1.2
F/R turkeys	73	73	0	0	0	0.0
Young turkeys	270	259	9	2	0	4.1
Mature turkeys	56	55	0	1	0	1.8
Ducks	172	167	5	0	0	2.9
Geese	13	13	0	0	0	2.9
Rabbits	47	39	8	0	0	17.0
TOTAL	4,704	4,307	381	15	1	8.4

Table B-9. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1980)

Species	Sample size	Concentration interval (ppm)[b] Not Detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	126	119	7	0	0	5.6
Steers	254	251	3	0	0	1.2
Cows	1,112	1,073	39	0	0	3.5
Heifers	243	242	1	0	0	0.4
Calves	406	347	58	1	0	14.5
Sheep[d]	241	233	7	1	0	3.3
Goats	91	86	5	0	0	5.5
Swine[e]	1,819	1,787	30	2	0	1.8
Horses	206	192	13	1	0	6.8
Young chickens	596	588	8	0	0	1.3
Mature chickens	550	546	4	0	0	0.7
F/R turkeys	127	124	3	0	0	2.4
Young turkeys	327	321	6	0	0	1.8
Mature turkeys	108	107	1	0	0	0.9
Ducks	258	256	2	0	0	0.8
Geese	19	19	0	0	0	0.0
Rabbits	44	43	1	0	0	2.3
TOTAL	6,527	6,334	188	5	0	3.0

Table B-10. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1981)

Species	Sample size	Concentration interval (ppm)[b] Not Detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	114	99	14	1	0	13.2
Steers	278	274	4	0	0	1.4
Cows	321	281	40	0	0	12.5
Heifers	275	263	12	0	0	4.4
Calves	278	239	38	1	0	14.0
Sheep[d]	377	336	39	2	0	10.9
Goats	140	115	23	2	0	17.9
Swine[e]	676	663	9	3	1	1.9
Horses	265	204	60	1	0	23.0
Young chickens	950	944	6	0	0	0.6
Mature chickens	698	696	2	0	0	0.3
F/R turkeys	136	135	1	0	0	0.7
Young turkeys	423	417	6	0	0	1.4
Mature turkeys	53	53	0	0	0	0.0
Ducks	344	342	2	0	0	0.6
Geese	--	--	--	--	--	--
Rabbits	46	46	0	0	0	0.0
TOTAL	5,374	5,107	256	10	1	5.0

Table B-11. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1982)

Species	Sample size	Concentration interval (ppm)[b] Not Detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	136	123	13	0	0	9.6
Steers	270	264	6	0	0	2.2
Cows	342	325	17	0	0	5.0
Heifers	267	263	4	0	0	1.5
Calves	305	272	30	3	0	10.8
Sheep[d]	246	235	11	0	0	4.5
Goats	94	86	8	0	0	8.5
Swine[e]	783	779	2	1	1	0.5
Horses	174	157	16	0	1	9.8
Young chickens	435	435	0	0	0	0.0
Mature chickens	348	346	2	0	0	0.6
F/R turkeys	64	64	0	0	0	0.0
Young turkeys	318	316	2	0	0	0.6
Mature turkeys	66	66	0	0	0	0.0
Ducks	153	153	0	0	0	0.0
Geese	4	4	0	0	0	0.0
Rabbits	45	45	0	0	0	0.0
TOTAL	4,050	3,933	111	4	2	2.9

Table B-12. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1983)

Species	Sample size	Concentration interval (ppm)[b] Not Detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	272	248	24	0	0	8.8
Steers	423	415	6	1	1	1.9
Cows	420	401	19	0	0	4.5
Heifers	404	391	12	0	1	3.2
Calves	653	605	47	1	0	7.4
Sheep[d]	565	515	50	0	0	8.8
Goats	223	203	19	0	1	9.0
Swine[e]	1,404	1,374	29	1	0	2.1
Horses	294	246	48	0	0	16.3
Young chickens	424	424	0	0	0	0.0
Mature chickens	441	438	3	0	0	0.7
F/R turkeys	65	65	0	0	0	0.0
Young turkeys	409	398	11	0	0	2.7
Mature turkeys	121	120	1	0	0	0.8
Ducks	332	327	5	0	0	1.5
Geese	32	32	0	0	0	0.0
Rabbits	69	66	3	0	0	4.3
TOTAL	6,551	6,268	277	3	3	4.3

Table B-13. Distribution of HCB Residue Levels in Animal Fat Samples[a] (Calendar Year 1984)

Species	Sample size	Concentration interval (ppm)[b] Not Detected[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Bulls	95	77	18	0	0	18.9
Steers	355	351	4	0	0	1.1
Cows	455	428	27	0	0	5.9
Heifers	223	212	11	0	0	4.9
Calves	616	571	44	1	0	7.3
Sheep[d]	342	308	33	0	1	9.9
Goats	133	116	17	0	0	12.8
Swine[e]	1,292	1,280	9	3	0	0.9
Horses	343	290	53	0	0	15.4
Young chickens	470	466	4	0	0	0.9
Mature chickens	886	879	7	0	0	0.8
F/R turkeys	85	83	2	0	0	2.4
Young turkeys	292	284	8	0	0	2.7
Mature turkeys	229	224	5	0	0	2.2
Ducks	323	320	3	0	0	0.9
Geese	25	24	1	0	0	4.0
Rabbits	95	91	3	1	0	4.2
TOTAL	6,259	6,004	249	5	1	4.0

Appendix C

Statistical Analysis of USDA HCB Residue Data in Domestic Meat and Poultry Fat Samples

Appendix C

Statistical Analysis of the USDA HCB Residue Data in Domestic Meat and Poultry Fat Samples

C.1 Introduction

In this Appendix, an analysis of data on categorical variables for HCB detection frequencies in livestock in the United States is presented. (A categorical variable is a variable with a small number of discrete levels in which the levels are treated as names (e.g., regions) rather than as representations of some ordered scale (e.g., the height of adult males).) The analysis uses a special class of statistical techniques called log-linear models. The results of such an analysis are presented in analysis of variance (ANOVA) formatted tables. The data used in this analysis were obtained from the U.S. Department of Agriculture and are discussed in Section 5.4. These data represent the HCB residue detection and nondetection frequencies in domestic meat and poultry fat samples classified by type of species, year, and geographic region. A series of ANOVA tables was obtained to determine sources of variation among the observed detection frequencies. When a source of variation proved to be significant, a multiple comparison of the percentages of that source was performed. A discussion of the analysis of variance for the log-linear models is presented in Section C.2. A definition of the factors considered in the analysis and their levels are given in Section C.3. Type of species, region, and time effects as sources of variance are investigated in Section C.4. A study of grazers and nongrazers, region, and time effects is presented in Section C.5. An analysis of type of species, region, and period effects is given in Section C.6. An analysis of grazers and nongrazers, species type, region, and period is also presented in Section C.6. The analysis of variance results in Sections C.4 through C.6 are followed by a comparison among the averages of the factors considered. Finally, an analysis of the HCB weighted detected frequencies is presented in Section C.7; the weight factors that were used represent the fractions of U.S. meat consumption in 1980.

C.2 Analysis of Variance Method for the Log-Linear Models

Log-linear models are a special class of the statistical models that have been formulated for the analysis of categorical data. In log-linear models, all variables (i.e., species types, time period, region) that are used for classification are considered as independent factors (inputs) and the number of cases in a cell (frequency) of the cross-tabulation is considered as the dependent variable (output). These models express the log of the observed frequency in each cell of the cross tabulation as a linear function of the main effects and interactions of the input factors.

An "analysis of variance" procedure is often used to test the significance of each of the main effects and interactions in the log-linear models. The analysis of variance method partitions the total variation present in the frequencies into several components. Associated with each of these components is a specific source of variation, so that in the analysis, it is possible to determine the magnitude of each source's contribution and the total variation. The components of the total variation in a set of data, and other related statistics, are usually displayed in an analysis table as shown in Table C-1. The first column in that table lists the sources of variation investigated. The first set of these sources comprises the main effects or the individual names of the classifying factors (e.g., type of species, region) considered in the analysis. The second set of sources shows the interactions between each pair of the classifying factors. A two-way interaction between a pair of factors exists if a change in one of the factors produces different changes in response in the levels (values) of the other factor. If more than two factors are investigated, then higher order interactions are displayed. The examination of an interaction between two or more factors requires the availability of more than one observation in each cross-classified cell of these factors. The total variation, because of main effects and interactions, is called explained or model variation. The unexplained part is called the residual, which is the part of the total variation caused by other factors not investigated.

Table C-1. Analysis of Variance Results for the HCB Detection Frequencies in Livestock by Year, Type of Species, and Region

Source of variation	DF	Sum of squares	Mean square	f	Significance of f (p-value)
Main effects					
Type	16	1,770.8	110.67	88.54	0.0001
Region	4	175.6	43.90	35.12	0.0001
Year	12	4,084.1	340.34	272.42	0.0001
Interactions					
Type by region	56	348.4	6.22	4.98	0.0001
Type by year	160	669.1	4.18	3.35	0.0001
Region by year	48	343.2	7.15	5.72	0.0001
Residual	336	419.8	1.25		
Total	632	7,810.8			

Associated with each source of the explained variations are the degrees of freedom (DF), sum of squares (SS), mean square (MS), f-values, and significance of the f-value (or the p-value). The degrees of freedom of a source are equal to the number of independent comparisons between the averages of the levels of that factor and the grand average of the factor. Therefore, the degrees of freedom of a source equal the number of levels of that source (e.g., for species type, the number of levels equals 17) minus one. SS of an explained source is the sum of the squares of the mean deviations of the source (e.g., all types of species) from the grand mean of the data. Therefore, the sum of squares tends to be large if the individual means vary considerably around the grand mean. The mean squares are obtained by dividing the sums of squares by the corresponding degrees of freedoms. Thus, the mean squares can be considered as the average of the sum of squares. The f-value of a source is obtained by dividing the mean square of source by the mean square of the residuals. This ratio follows a probability distribution known as the F distribution. The significance of f (or the p-value) is the area to the right of the f-value under the probability curve of the F distribution. Therefore, the p-value of a source of a variation is the probability that the contribution of that source to the total variation is <u>not</u> significant. Accordingly, if the p-value is small, there is a high probability (1-p) that the contribution is significant.

The p-value is considered small if it does not exceed a preassigned level known as the significance level. The significance level assigned in this study is 0.05.

The Statistical Analysis System (SAS) package on the IBM 370 mainframe computer was used to obtain all the statistical results in this study. The SAS general linear model (GLM) procedure was used to model the detection frequencies. In this procedure, a function of the detection percentages called a "logit" function was calculated. This function models the logs of ratios of binomial probabilities. The detection frequencies or counts are assumed to follow a binomial

distribution. The classifying factors group the observed frequencies into S samples, where S is the number of possible combinations of the classifying factors. Each possible combination of the classifying factors (e.g., a specific year with a specific region) is considered a sample from a binomial distribution. The binomial distribution has two possible responses (i.e., detected and not detected). Each sample, i, is assumed to represent the population from which it was drawn. In other words, the probability of detection in the overall population is estimated by the percentage of detection in the sample. A logit value is equal to the natural logarithm of the ratio of the first response (detection) percentage to the second response (nondetection) percentage. These logit values follow a normal distribution and the logit function is a necessary transformation to achieve normality. Normality is an essential condition to apply the analysis of variance procedure.

C.3 Factors Considered in the Analysis

The classification of the data for the detected HCB residue levels in livestock permitted the following factors and their interactions to be investigated for possible significant contributions in the total variation of the data.

Time. Changes over time in the data are investigated. The 13 years (1972 to 1984) are considered to be the levels of the time factor.

Regions. Differences among regions are considered as a possible factor. The five regions (1 - West, 2 - Southwest, 3 - North Central, 4 - Southeast, 5 - Northeast) are considered.

Types of Species. Differences among 17 types of species are considered as factors. The types are: 1 - horse; 2 - bull; 3 - steer; 4 - cow; 5 - heifer; 6 - calf; 7 - sheep; 8 - goat; 9 - swine; 10 - young chicken; 11 - mature chicken; 12 - fryer-roaster (f/r) turkey; 13 - young turkey; 14 - mature turkey; 15 - duck; 16 - goose; and 17 - rabbit.

Grazers and Nongrazers. The types of species can be classified, according to the feeding method, into two groups: 1 - grazers and

2 - nongrazers. The grazers group includes the first eight types of species (horse, bull, steer, cow, heifer, calf, sheep, and goat). The nongrazers group includes the last nine types of species (swine, young chicken, mature chicken, f/r turkey, young turkey, mature turkey, duck, goose, and rabbit). The differences between these two groups are considered as a source of variation in the data. Since this factor is a grouping of the types of species, these two factors (types of species and grazers - nongrazers) will not be investigated together in the analysis.

C.4 Type of Species, Region, and Time Effects

The first analysis was performed to investigate the significance of the main effects and interactions of the three factors, i.e., type of species, regions, and years (1972-1984) as a source of variation. The three-way interaction among these three factors was not investigated because of the unavailability of more than one observation in each of the cross-classified cells of the three factors. The analysis of variance results are given in Table C-1.

The following conclusions were derived from the data in Table C-1:

1. Each of the main effects (type of species, region, and year) has a significant contribution to the total variation of the detected frequencies (each has a p-value <0.05).

2. Each of the two-way interactions of type of species by region, type of species by year, and region by year has a significant contribution to total variation of the detected frequencies (each has a p-value <0.05).

The three-way (types of species, regions, years) cross-classified HCB detection percentages were aggregated by each one of the three factors and the results are listed in Tables C-2, C-3, and C-4. A cross-classification by types of species and regions is presented in Table C-2, a cross-classification by types of species and years is

Table C-2. Averages of the HCB Detection Frequencies in Livestock by Type of Species and Region

Types of species	Regions					Nationwide
	West	Southwest	North Central	Southeast	Northeast	
Horse	44.1	27.7	43.1	15.9	49.3	33.6
Bull	26.3	23.1	30.7	18.3	27.5	25.5
Steer	17.0	6.3	9.4	8.3	8.1	9.9
Cow	28.8	28.6	26.7	22.7	20.4	26.2
Heifer	10.3	11.0	9.0	27.5	25.0	10.8
Calf	14.7	14.2	23.7	24.0	34.4	27.4
Sheep	23.8	18.5	17.8	25.6	21.7	20.9
Goat	10.9	33.0	18.2	21.3	18.7	24.6
Swine	3.0	3.9	3.1	1.8	4.1	3.0
Young chicken	5.8	10.7	4.4	4.3	14.2	7.2
Mature chicken	16.8	7.2	4.3	5.1	5.8	6.4
Fryer-roaster turkey	23.1	33.3	13.8	5.0	27.5	18.1
Young turkey	12.4	12.5	7.8	8.6	19.2	10.8
Mature turkey	13.1	4.8	13.4	14.2	11.8	12.8
Duck	1.4	10.5	4.0	0	2.6	3.2
Goose	1.0	-*	7.0	-*	-*	4.2
Rabbit	0	14.5	7.1	13.5	-*	14.2
All types (unweighted)	18.7	16.3	11.7	8.9	20.1	14.3

*Data were not available to compute this percentage.

Table C-3. Averages of the HCB Detection Frequencies in Livestock by Types of Species and Years

Type of species	Year													Whole period
	72	73	74	75	76	77	78	79	80	81	82	83	84	
Horse	-	0	33.6	75.5	82.0	82.1	35.6	24.1	6.8	23.0	9.8	16.3	15.5	33.6
Bull	0	28.6	63.9	60.2	60.9	75.0	26.7	17.4	5.6	13.2	9.6	8.8	19.0	25.5
Steer	8.0	8.5	18.8	20.2	26.8	28.6	21.5	6.1	1.2	1.4	2.2	1.9	1.1	9.9
Cow	13.9	7.6	51.5	52.1	42.5	56.1	32.7	11.6	3.5	12.5	5.0	4.5	5.9	26.2
Heifer	1.9	1.8	19.3	21.8	31.0	33.7	28.2	6.2	0.4	4.4	1.5	3.2	4.9	10.8
Calf	0	34.5	75.9	63.9	64.2	67.7	39.6	20.9	14.5	14.0	10.8	7.4	7.3	27.4
Sheep	13.0	17.3	50.2	50.3	49.0	58.7	27.2	15.8	3.3	10.9	4.5	8.9	9.9	20.9
Goat	-	20.0	68.3	62.5	77.3	80.0	40.0	8.8	5.5	17.9	8.5	9.0	12.8	24.6
Swine	3.1	1.3	8.6	4.9	5.0	7.4	19.3	1.8	1.8	1.9	0.5	2.1	0.9	3.0
Young chicken	6.3	4.4	20.1	25.7	21.3	18.6	13.0	3.0	1.3	0.6	0	0	0.9	7.2
Mature chicken	2.1	0.8	13.8	17.6	15.9	27.3	12.8	1.2	0.7	0.3	0.6	0.7	0.8	6.4
Fryer-roaster turkey	2.3	1.8	22.2	44.0	50.9	50.0	26.0	0	2.4	0.7	0	0	2.4	18.1
Young turkey	2.5	4.2	15.0	37.2	44.5	33.3	19.7	4.1	1.8	1.4	0.6	2.7	2.7	10.8
Mature turkey	-	27.9	11.1	30.5	34.5	33.3	47.6	1.8	0.9	0	0	0.8	2.2	12.8
Duck	-	0	0	8.9	9.4	4.6	13.0	2.9	0.8	0.6	0	1.5	0.9	3.2
Goose	-	0	12.5	0	4.8	10.0	0	0	0	-	0	0	4.0	4.2
Rabbit	-	-	21.1	18.3	32.3	85.7	20.7	17.0	2.3	0	0	4.4	4.2	14.2
All types	5.2	7.0	30.0	35.6	35.4	40.6	25.7	8.4	3.0	5.0	2.9	4.3	4.1	14.3

Table C-4. Averages of the HCB Detection Frequencies in Livestock by Region and Year

Year	Regions					
	West	Southwest	North Central	Southeast	Northeast	Nationwide
1972	12.6	5.0	2.5	4.3	3.1	5.2
1973	19.5	6.3	3.8	4.0	6.9	7.0
1974	34.3	39.5	21.6	20.6	40.5	30.0
1975	55.1	40.5	23.8	21.4	44.4	35.6
1976	50.0	43.3	27.4	25.8	38.5	35.4
1977	46.4	55.2	31.3	40.5	43.2	40.6
1978	9.3	17.4	32.7	23.6	35.0	25.7
1979	2.8	12.6	8.8	4.3	11.7	8.4
1980	0.9	1.4	2.9	2.7	6.5	3.0
1981	3.9	5.4	4.5	3.7	9.7	5.0
1982	1.0	3.4	3.3	0.6	7.6	2.9
1983	7.7	5.2	3.7	0.3	6.2	4.3
1984	6.2	6.8	2.3	1.4	6.1	4.1
Overall	18.7	16.3	11.7	8.9	20.1	14.3

shown in Table C-3, and a cross-classification by regions and years is found in Table C-4. The results in these tables show the following:

1. The total percentages of detection for each type of species are considerably different from the grand total percentage of detection (Tables C-2 and C-3). Horse, bull, cow, calf, sheep, goat (grazers type) and f/r turkey (nongrazers type) have higher total percentages of detection compared to the grand total percentage of detection. Steer, heifer (grazers type), swine, young chicken, mature chicken, young turkey, mature turkey, duck, goose, and rabbit (nongrazer type) have lower total percentages of detection compared to the grand total percentage of detection. A test of the grazers and nongrazers type effects with the other factors is discussed in Section C.5.

2. West, Southwest, and Northeast regions have higher percentages of detection compared to the grand total percentage of detection. North central and southeast regions have lower total percentages of detection compared to the grand total percentage of detection (Tables C-2 and C-4).

3. The total percentages of detection for the individual years are considerably different from the grand total percentage of detection (Tables C-3 and C-4). Each of the total percentages for the years 1972, 1973, and 1979 to 1984 is considerably smaller than the grand total percentage (more than 35 percent lower). Each of the total percentages of detection for the years 1974 to 1978 is considerably larger than the grand total percentage of detection (more than 78 percent higher).

4. The detection percentages for each region (Table C-2) have a different type of species behavior from that of the overall type of species conclusion discussed above. Moreover, the detection percentages for each type of species (Table C-2) have a different regional behavior from the overall regional conclusion discussed above. These results are another indication of the significant type of species by region interaction conclusion given in Table C-1.

5. Most of the detection percentages for years 1974 to 1978, cross-classified by horse, bull, cow, calf, sheep, f/r turkey, mature turkey, and rabbit, are relatively higher than the grand total percentage of detection (see Table C-3).

6. The detection percentages for years 1972, 1973, and 1979 to 1982 have different regional behavior from the overall regional conclusion discussed above.

To examine the effects of years and regions for each type of species, separate analysis of variance (without interaction) studies were performed. The 17 analysis of variance studies are summarized in Table C-5. They indicate that:

1. Region is not a significant factor for bull, cow, swine, mature turkey, duck, and rabbit. However, region is a significant factor for all other species (p-value <0.05).

2. All types of species, except rabbit, have significant year effect.

C.5 Grazers/Nongrazers, Region, and Time Effects

To examine the grazers/nongrazers type of species effect and its interactions with region and year, an analysis of variance for these three factors was performed. The results are given in Table C-6. The following conclusions were derived from the data in Table C-6:

1. There are significant main effects because of grazers/nongrazers, region, and year (each has a p-value <0.05).

2. There is a significant two-way interaction of grazers/nongrazers by region, grazers/nongrazers by year, and region by year (each has a p-value <0.05).

3. The three-way interaction of grazers/nongrazers by region by year is not significant.

Table C-5. Analysis of Variance Results for the Types of Species by Region and Year

Type of species	Region (p-level)	Year (p-level)
Horse	0.0001	0.0001
Bull	0.2650	0.0001
Steer	0.0090	0.0002
Cow	0.2500	0.0001
Heifer	0.0200	0.0001
Calf	0.0005	0.0001
Sheep	0.0446	0.0001
Goat	0.0005	0.0001
Swine	0.0927	0.0001
Young chicken	0.0001	0.0001
Mature chicken	0.0001	0.0001
Fryer roaster/turkey	0.0079	0.0087
Young turkey	0.0001	0.0001
Mature turkey	0.3873	0.0266
Duck	0.1867	0.0079
Goose	-- *	-- *
Rabbit	0.3197	0.3628

*Insufficient cross-classified data were available to perform this analysis.

Table C-6. Analysis of Variance Results for the HCB Detection Frequencies in Livestock by Grazers/Nongrazers, Region, and Year

Source of variation	DF	Sum of squares	Mean square	f	Significance of f (p-value)
Main effects					
Grazers/nongrazers	1	837.0	837.00	207.35	0.0001
Region	4	212.1	53.02	13.14	0.0001
Year	12	3,909.7	325.81	8,071.0	0.0001
Interactions					
Grazers/nongrazers type by region	4	208.6	52.15	12.92	0.0001
Grazers/nongrazers type by year	12	100.4	8.37	2.07	0.0172
Region by year	48	390.7	8.14	2.02	0.0001
Grazers/nongrazers type by region by year	42	97.6	2.32	0.58	0.9855
Residual	509	2,054.6	4.04		
Total	632	7,810.8			

To illustrate the differences between grazer and nongrazer types and their interactions with region and year, cross-classifications of HCB detection percentages by grazers/nongrazers type with region and by grazers/nongrazers type with year were obtained and presented in Tables C-7 and C-8. The results in Tables C-7 and C-8 show the following:

1. The nationwide detection percentage for grazers type is higher (60 percent) than the overall detection percentage. The nationwide detection percentage for nongrazers type is lower (54 percent) than the overall detection percentage.

2. For each region, the detection percentage for grazers type is higher and for nongrazers type it is lower than the total detection percentage for that region; however, the actual differences in the detection percentages vary among regions compared to nationwide differences for all types of species.

3. For each year, the detection percentage for grazers type is higher and for nongrazers type it is lower than the overall detection percentage for all years combined; however, the actual differences in the detection percentages vary among years compared to overall differences for all species.

C.6 Type of Species, Region, and Period Effects.

The classification of HCB detection percentages by years (1972 to 1984) showed different historical behavior within the period 1974 to 1978 from that within the period 1972 to 1973 and 1979 to 1984. To examine the effects of the three periods and interactions with types of species and region, an analysis of variance for these factors was performed and the results are presented in Table C-9. The results show the following:

1. Each of the main effects of type of species, region, and period has a significant contribution to the total variation of the detected frequencies (each has a p-value <0.05).

Table C-7. Averages of the HCB Detection Frequencies by Grazers and Nongrazers Type and Region

Region	Grazer/Nongrazer Type		
	Grazers	Nongrazers	All types
West	23.7	9.8	18.7
Southwest	20.5	9.3	16.3
North Central	21.8	4.8	11.7
Southeast	21.6	4.8	8.9
Northeast	21.6	10.6	20.1
Nationwide	22.9	6.6	14.3

Table C-8. Averages of the HCB Detection Frequencies in Livestock by Type (Grazer/Nongrazer) and Year

Year	Type		Both types combined
	Grazers	Nongrazers	
1972	9.3	3.2	5.2
1973	11.8	3.0	7.0
1974	47.8	14.9	30.0
1975	45.9	21.8	35.6
1976	48.2	20.1	35.4
1977	56.9	22.6	40.6
1978	32.5	17.5	25.7
1979	14.8	2.4	8.4
1980	5.1	1.5	3.0
1981	11.6	0.9	5.0
1982	5.9	0.4	2.9
1983	7.1	1.6	4.3
1984	8.2	1.2	4.1
Overall	22.9	6.6	14.3

Table C-9. Analysis of Variance Results for the HCB Detection Frequencies in Livestock by Type of Species, Region, and Period*

Source of variation	DF	Sum of squares	Mean square	f	Significance of f (p-value)
Main effects					
Type	16	1,770.7	110.67	35.99	0.0001
Region	4	175.6	43.90	14.27	0.0001
Period	2	3,775.6	1,887.80	613.84	0.0001
Interactions					
Species type by region	56	431.8	7.71	2.51	0.0001
Species type by period	28	90.7	3.24	1.05	0.3926
Region by period	8	47.2	5.90	1.92	0.0554
Species type by region by period	69	138.3	2.00	0.65	0.9852
Residual	449	1,380.9	3.07		
Total	632	7,810.8			

*Period refers to the three time periods assumed in this analysis: 1972-1973, 1974-1978, and 1979-1984.

2. Type of species by region interaction is significant (p-value <0.05). Type of species by period interaction, region by period interaction, and type of species by region by period interaction are not significant.

A cross-classification of the HCB detection percentages by types of species and periods is presented in Table C-10. A cross-classification of the HCB detection percentages by regions and periods is found in Table C-11. The results in Tables C-10 and C-11 show the following:

1. The HCB detection percentage for the period 1974 to 1978 is larger (135 percent) than the grand total detection percentage, and the HCB detection percentages are lower for period 1972 to 1973 and 1979 to 1984 (55 percent and 69 percent, respectively) than the grand total detection percentage.

2. The percentages for each type of species, except calf and mature turkey (see Table C-10), have a similar behavior to that of the overall percentages discussed above (higher for period 1974 to 1978, and lower for periods 1972 to 1973 and 1979 to 1984) than the grand total detection percentage.

3. The percentages for each region have a similar behavior to that of the overall percentages (higher for period 1974 to 1978, and lower for periods 1972 to 1973 and 1979 to 1984).

To test the significance of the interaction of period with grazers/nongrazers type of species and region, an analysis of variance for these three factors was performed and the results are listed in Table C-12. The results in Table C-12 show the following:

1. There are significant main effects because of grazers/nongrazers type of species, region, and period.

2. There is a significant interaction of grazers/nongrazers type by region, and grazers/nongrazers type by period. The two-way interaction of region by period and the three-way interaction of grazers/nongrazers type by region by period are not significant.

Table C-10. Averages of the HCB Detection Frequencies in Livestock by Types of Species and Time Period

Types of species	Period			All periods
	1972-1973	1974-1978	1978-1984	
Horse	0	62.7	16.2	33.6
Bull	22.2	59.5	11.0	25.5
Steer	8.3	22.1	1.9	9.9
Cow	8.0	46.0	7.0	26.2
Heifer	1.8	25.7	3.2	10.8
Calf	30.5	63.0	12.1	27.4
Sheep	15.8	48.6	8.8	20.9
Goat	20.0	68.4	10.8	24.6
Swine	1.9	9.4	1.6	3.0
Young chicken	5.4	20.7	0.8	7.2
Mature chicken	1.3	17.1	0.7	6.4
Fryer-roaster turkey	2.0	36.5	1.1	18.1
Young turkey	3.7	27.7	2.2	10.8
Mature turkey	27.9	33.2	1.3	12.8
Duck	0	7.4	1.1	3.2
Goose	0	8.0	1.1	4.2
Rabbit	-*	30.2	4.6	14.2
All types (unweighted)	6.4	33.6	4.5	14.3

*Data were not available to compute this percentage.

Table C-11. Averages of the HCB Detection Frequencies by Region and Period

Region	Period			Whole period
	1972-1973	1974-1978	1979-1984	
West	17.1	43.2	4.1	18.7
Southwest	6.0	39.7	5.6	16.3
North Central	3.4	26.6	4.2	11.7
Southeast	4.1	25.3	2.1	8.9
Northeast	5.7	40.6	7.8	20.1
Nationwide	6.4	33.6	4.5	14.3

Table C-12. Analysis of Variance Results for the HCB Detection Frequencies in Livestock by Grazers/Nongrazers Type, Region, and Period*

Source of variation	DF	Sum of squares	Mean square	f	Significance of f (p-value)
Main effects					
Grazers/nongrazers type	1	837.0	837.00	184.46	0.0001
Region	4	212.1	53.02	11.69	0.0001
Period	2	3,680.2	1,840.10	405.53	0.0001
Interactions					
Grazers/nongrazers type by region	4	208.6	52.15	11.50	0.0001
Grazers/nongrazers type by period	2	32.1	16.05	3.54	0.0295
Region by period	8	65.0	8.12	1.79	0.0760
Grazers/nongrazers type by region by period	8	39.7	4.96	1.09	0.3657
Residual	603	2,736.1	4.54		
Total	632	7,810.8			

*Period refers to the three time periods assumed in this analysis: 1972-1973, 1974-1978, and 1979-1984.

A cross-classification of the HCB detection percentages by grazers/nongrazers type and by period is presented in Table C-13. The results in Table C-13 show that the HCB detection frequencies for each period are higher for grazers type and lower for nongrazers type than the overall HCB detection frequencies for the two types combined in that period.

To examine the effects of region and periods for grazers and for nongrazers type of species, separate analysis of variance studies were performed. The two analysis of variance studies are summarized in Table C-14. The results indicate that:

1. Region effect and period effect are significant for grazers and also for nongrazers type of species.

2. The interaction of region by period is not significant for grazers and nongrazers type of species.

An examination of the region effect from the period 1974 to 1978 was performed for grazers and nongrazers, separately and combined, and the results are listed in Table C-15. The results showed that for the period 1974 to 1978, region is significant for grazers, nongrazers, and the two types combined.

A cross-classification of the HCB detection percentages by grazers/nongrazers type and by region for the period 1974 to 1978 is presented in Table C-16. The following was concluded from the data in Table C-16 for the period 1974 to 1978.

1. For the entire nation and for each region, the detection percentages for grazers type are higher than the overall detection percentages. The detection percentages for nongrazers are lower than the overall detection percentages found for each region and nationwide.

Table C-13. Averages of the HCB Detection Frequencies in Livestock by Period and Type (Grazer/Nongrazer)

Period	Type		Two types together
	Grazer	Nongrazer	
1972-1973	11.2	3.0	6.4
1974-1978	46.4	19.1	33.6
1979-1984	8.6	1.3	4.5
Total period 1972-1984	22.4	6.6	14.3

Table C-14. Analysis of Variance Results for Grazers and Nongrazers by Region and Period

Type	Region (p-level)	Period (p-level)	Region by period (p-level)
Grazers	0.0385	0.0001	0.0691
Nongrazers	0.0001	0.0001	0.4458

Table C-15. Analysis of Variance Results for the Grazers and Nongrazers Type of Species by Region for the Period 1974 to 1978

Type	Region (p-level)
Grazers	0.0069
Nongrazers	0.0001
Two types combined	0.0001

Table C-16. Averages of the HCB Detection Frequencies in Livestock by Type (Grazer/Nongrazer) and Region for the Period 1974 to 1978

Region	Grazers	Nongrazers	All types
West	49.0	29.2	43.2
Southwest	46.0	27.9	39.7
North Central	39.4	12.9	26.6
Southeast	47.6	15.6	25.3
Northeast	59.1	24.0	40.6
Nationwide	46.4	19.1	33.6

2. The detection percentages for nongrazers type of species have a similar regional behavior to that of the two types combined. The detection percentages for grazers type of species in the Southwest and Southeast regions differ significantly from that for the types of species combined in these two regions.

C.7 Analysis of Weighted Frequencies

In all the analyses discussed in this Appendix so far, equal weights for the types of species were used. A weighted aggregation over types of species was obtained by weighting each type of species by the poundage of dressed meat and ready-to-cook poultry produced in the United States in 1980. The weights that were used are presented in Table C-17.

An analysis of variance study for the weighted detection frequencies was performed to determine whether there were significant changes over time and/or significant differences among regions; the results are listed in Table C-18. The following conclusions were derived from the data in Table C-18:

1. Differences among years and among regions have significant effects on the total variation of the weighted detection frequencies (each has a p-value <0.05).

2. The interaction between years and regions is significant (p-value <0.05).

An analysis of variance study for the weighted frequencies to examine the effects of regions, periods, and their interaction was performed and the results are listed in Table C-19. The following conclusions were derived from the data in Table C-19:

1. Region is a significant factor (p-value <0.05).

2. Period is a significant factor (p-value <0.05).

3. Interaction between regions and periods is not a significant factor (p-value <0.05).

Table C-17. Weight Fractions of U.S. Meat Consumption in 1980

Species	All species
Horse	0.0040
Bull	0.0099
Steer	0.2219
Cow	0.0592
Heifer	0.1060
Calf	0.0059
Sheep	0.0059
Goat	0.0001
Swine	0.3085
Young chicken	0.2183
Mature chicken	0.0125
Fryer-roaster turkey	0.0015
Young turkey	0.0441
Mature turkey	0.0004
Duck	0.0016
Goose	0.0001
Rabbit	0.0001
	1.0000

Sources: USDA (1981) and USDA (1982).

Table C-18. Analysis of Variance Results for the HCB Weighted Detection Frequencies in Livestock by Region and Year

Source of variation	DF	Sum of squares	Mean square	f	Significance of f (p-value)
Main effects					
Region	4	47.5	11.87	32.88	0.0001
Year	12	295.4	24.62	68.20	0.0001
Interactions					
Region by year	48	25.0	0.52	1.44	0.0309
Residual	568	205.0	0.36		
Total	632	572.9			

Table C-19. Analysis of Variance Results for the Weighted HCB Detection Frequencies in Livestock by Region and Period

Source of variation	DF	Sum of squares	Mean square	f	Significance of f (p-value)
Main effects					
Region	4	47.5	11.87	30.79	0.0001
Period	2	283.5	141.75	369.70	0.0001
Interactions					
Region by period	8	3.7	0.46	1.21	0.2976
Residual	618	238.2	0.39		
Total	632	572.9			

C.8 References

USDA. 1981. Livestock slaughter - annual summary 1980. Washington, DC: Economics and Statistics Service, Crop Reporting Board, U.S. Department of Agriculture.

USDA. 1982. Agricultural statistics (Table 481), 1982.

Appendix D

HCB Detection Frequencies in Domestic Meat and Poultry Fat Samples (Graphical Data by Species and Year - 1972 to 1984)

(Source: Data Supplied by USDA/FSIS)

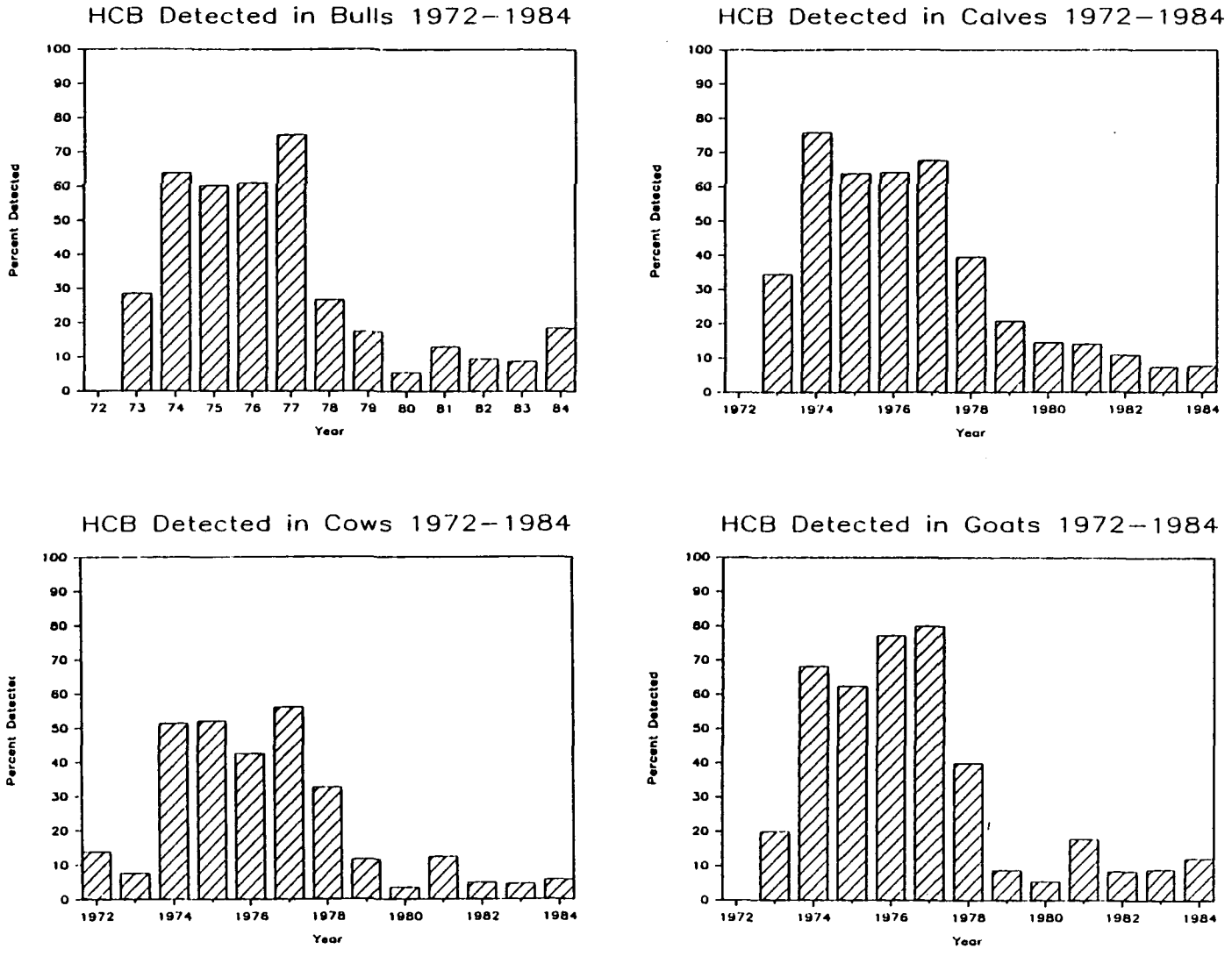


Figure D-1. HCB detection frequency in bulls, calves, cows, and goats, 1972-1984.

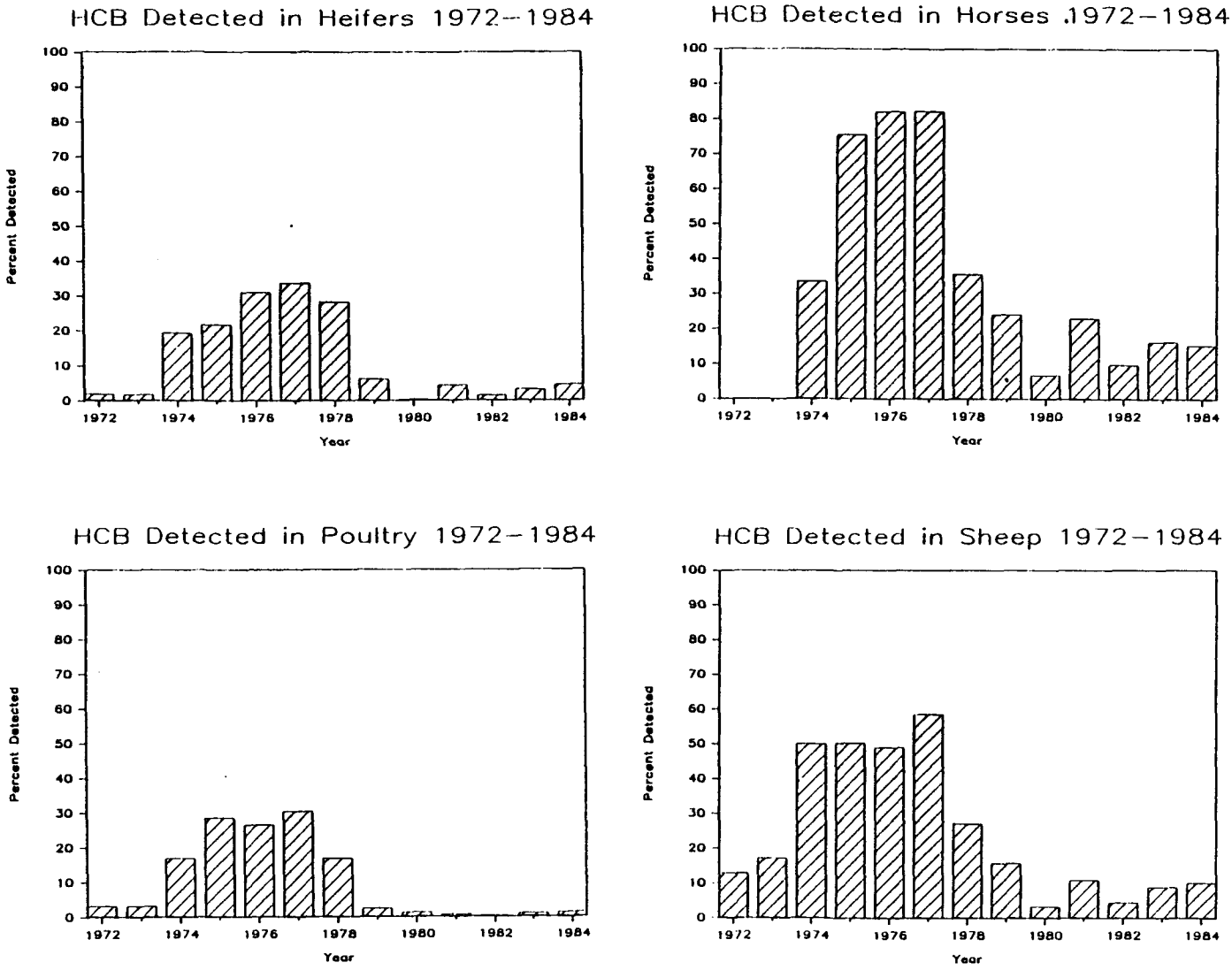


Figure D-2. HCB detection frequency in heifers, horses, poultry, and sheep, 1972-1984.

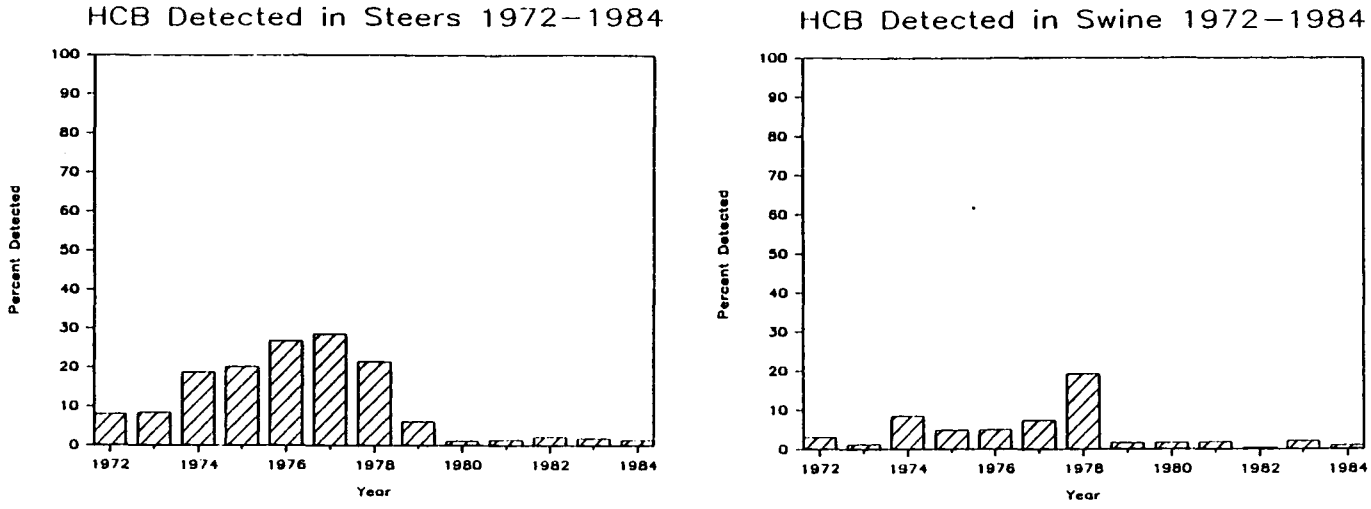


Figure D-3. HCB detection frequency in steers and swine, 1972-1984.

Appendix E

HCB Detection Frequencies in Imported Meat and Poultry (1979 to June 1984)

Table E-1. USDA National Residue Monitoring Program Summary of HCB Residues Found in Imported Meat and Poultry for Calendar Years 1979 - June 30, 1984

Country	Calendar year[a]	Sample size	Concentration interval[b] (ppm) ND[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Argentina	1979	359	220	137	2	0	38.7
	1980	207	141	63	2	1	31.9
	1981	42	36	6	0	0	14.3
	1982	170	145	25	0	0	14.7
	1983	187	176	10	1	0	6.5
	1984	83	78	5	0	0	6.0
Australia	1979	177	167	10	0	0	5.6
	1980	183	176	7	0	0	3.8
	1981	30	30	0	0	0	0.0
	1982	205	201	4	0	0	2.0
	1983	153	151	2	0	0	1.3
	1984	55	54	1	0	0	1.8
Belgium	1979	22	2	20	0	0	90.9
	1980	18	4	14	0	0	77.8
	1981	46	38	7	1	0	17.4
	1982	214	198	16	0	0	7.5
	1983	179	174	5	0	0	2.8
	1984	93	93	0	0	0	0.0
Brazil	1979	107	99	8	0	0	7.5
	1980	197	183	14	0	0	7.1
	1981	30	30	0	0	0	0.0
	1982	115	111	4	0	0	3.5
	1983	172	172	0	0	0	0.0
	1984	85	82	3	0	0	3.5
Bulgaria	1979	2	2	0	0	0	0.0
	1980	10	8	2	0	0	20.0
Canada	1979	256	242	13	1	0	5.5
	1980	305	272	33	0	0	10.8
	1981	171	166	5	0	0	2.9
	1982	450	438	12	0	0	2.7
	1983	606	599	7	0	0	1.2
	1984	277	275	1	1	0	0.7
Rep. of China	1980	1	1	0	0	0	0.0
	1982	2	2	0	0	0	0.0

Table E-1. (continued)

Country	Calendar year[a]	Sample size	Concentration interval[b] (ppm) ND[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Costa Rica	1979	155	148	7	0	0	4.5
	1980	124	119	5	0	0	4.0
	1981	36	36	0	0	0	0.0
	1982	76	74	1	1	0	2.6
	1983	44	44	0	0	0	0.0
	1984	37	37	0	0	0	0.0
Czechoslovakia	1979	47	9	28	10	0	80.8
	1980	89	12	64	12	1	86.5
	1981	31	9	20	1	1	71.0
	1982	66	36	26	4	0	45.4
	1983	29	18	11	0	0	37.9
	1984	17	17	0	0	0	0.0
Denmark	1979	155	134	21	0	0	13.5
	1980	403	383	19	1	0	5.0
	1981	258	247	10	1	0	4.3
	1982	659	644	14	1	0	2.3
	1983	330	327	3	0	0	0.9
	1984	320	317	3	0	0	0.9
Dominican Rep.	1979	15	13	2	0	0	13.3
	1980	22	22	0	0	0	0.0
	1981	13	12	1	0	0	7.7
	1982	101	99	2	0	0	2.0
	1983	62	62	0	0	0	0.0
	1984	12	12	0	0	0	0.0
El Salvador	1979	57	54	1	2	0	5.3
	1980	45	45	0	0	0	0.0
	1981	2	2	0	0	0	0.0
	1982	32	32	0	0	0	0.0
	1983	22	22	0	0	0	0.0
	1984	8	8	0	0	0	0.0
Finland	1983	55	55	0	0	0	0.0
	1984	37	37	0	0	0	0.0

Table E-1. (continued)

Country	Calendar year[a]	Sample size	Concentration interval[b] (ppm) ND[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
France	1979	13	9	4	0	0	30.8
	1980	22	13	9	0	0	40.9
	1981	7	7	0	0	0	0.0
	1982	22	20	2	0	0	9.1
	1983	29	25	4	0	0	13.8
	1984	13	13	0	0	0	0.0
Germany	1979	11	10	1	0	0	9.1
	1980	10	10	0	0	0	0.0
	1981	5	2	3	0	0	60.0
	1982	14	13	1	0	0	7.1
	1983	12	12	0	0	0	0.0
	1984	10	10	0	0	0	0.0
Guatemala	1979	122	118	3	1	0	3.3
	1980	97	89	8	0	0	8.2
	1981	3	3	0	0	0	0.0
	1982	11	11	0	0	0	0.0
	1983	34	34	0	0	0	0.0
	1984	29	29	0	0	0	0.0
Haiti	1979	28	26	2	0	0	7.1
	1980	30	30	0	0	0	0.0
	1981	7	6	1	0	0	14.3
	1982	15	14	1	0	0	6.7
	1983	14	14	0	0	0	0.0
	1984	1	1	0	0	0	0.0
Honduras	1979	97	92	5	0	0	5.2
	1980	204	190	14	0	0	6.9
	1981	24	24	0	0	0	0.0
	1982	56	53	3	0	0	5.4
	1983	92	92	0	0	0	0.0
	1984	18	18	0	0	0	0.0
Hong Kong	1979	50	40	10	0	0	20.0
	1980	14	13	1	0	0	7.1
	1981	5	5	0	0	0	0.0
	1982	17	13	3	1	0	23.5
	1983	12	12	0	0	0	0.0
	1984	3	3	0	0	0	0.0

Table E-1. (continued)

Country	Calendar year[a]	Sample size	Concentration interval[b] (ppm) ND[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Hungary	1979	74	68	6	0	0	8.1
	1980	76	69	7	0	0	9.2
	1981	24	24	0	0	0	0.0
	1982	74	72	2	0	0	2.7
	1983	110	106	4	0	0	3.6
	1984	31	31	0	0	0	0.0
Iceland	1979	4	1	2	1	0	75.0
	1981	3	2	1	0	0	33.3
	1982	2	2	0	0	0	0.0
	1983	1	1	0	0	0	0.0
	1984	3	2	1	0	0	33.3
Ireland	1979	17	16	1	0	0	5.9
	1980	247	185	62	0	0	25.1
	1981	7	6	1	0	0	14.3
	1982	154	124	30	0	0	19.5
	1983	310	292	18	0	0	5.8
	1984	35	34	1	0	0	2.8
Israel	1981	1	0	1	0	0	100.0
	1982	8	8	0	0	0	0.0
	1983	24	23	1	0	0	4.2
	1984	8	8	0	0	0	0.0
Italy	1979	16	2	14	0	0	87.5
	1980	12	2	10	0	0	83.3
	1981	3	0	3	0	0	100.0
	1982	16	9	7	0	0	43.8
	1983	19	19	0	0	0	0.0
	1984	3	0	3	0	0	100.0
Mexico	1979	11	11	0	0	0	0.0
	1983	156	151	4	1	0	3.2
	1984	7	7	0	0	0	0.0
Netherlands	1979	31	16	15	0	0	48.4
	1980	33	22	10	1	0	33.3
	1981	15	13	2	0	0	13.3
	1982	58	49	8	1	0	15.5
	1983	59	59	0	0	0	0.0
	1984	38	37	1	0	0	2.6

Table E-1. (continued)

Country	Calendar year[a]	Sample size	Concentration interval[b] (ppm) ND[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
New Zealand	1979	321	303	18	0	0	5.6
	1980	274	259	15	0	0	5.5
	1981	38	36	1	1	0	5.3
	1982	270	264	6	0	0	2.2
	1983	250	248	2	0	0	0.8
	1984	111	111	0	0	0	0.0
Nicaragua	1979	265	255	10	0	0	3.8
	1980	81	79	2	0	0	2.5
	1981	11	11	0	0	0	0.0
	1982	43	43	0	0	0	0.0
	1983	41	41	0	0	0	0.0
	1984	13	13	0	0	0	0.0
Panama	1979	5	5	0	0	0	0.0
	1980	24	24	0	0	0	0.0
	1981	15	15	0	0	0	0.0
	1982	34	34	0	0	0	0.0
	1983	42	42	0	0	0	0.0
	1984	3	3	0	0	0	0.0
Paraguay	1979	8	8	0	0	0	0.0
	1980	1	1	0	0	0	0.0
Poland	1979	200	177	21	2	0	11.5
	1980	192	167	24	1	0	13.0
	1981	12	11	1	0	0	8.3
	1982	74	72	1	1	0	2.7
	1983	123	119	4	0	0	3.2
	1984	62	61	1	0	0	1.6
Romania	1979	137	110	26	1	0	19.7
	1980	105	83	22	0	0	21.0
	1981	15	15	0	0	0	0.0
	1982	32	29	3	0	0	9.4
	1983	38	38	0	0	0	0.0
	1984	8	8	0	0	0	0.0
Sweden	1983	21	21	0	0	0	0.0
	1984	182	182	0	0	0	0.0

Table E-1. (continued)

Country	Calendar year[a]	Sample size	Concentration interval[b] (ppm) ND[c]	0.01-0.10	0.11-0.50	>0.50	Percent detected
Switzerland	1979	10	10	0	0	0	0.0
	1980	15	9	6	0	0	40.0
	1981	15	13	2	0	0	13.3
	1982	33	26	7	0	0	21.2
	1983	34	26	8	0	0	23.5
	1984	18	16	2	0	0	11.1
Taiwan	1980	31	29	2	0	0	6.4
	1981	21	21	0	0	0	0.0
	1982	50	50	0	0	0	0.0
	1983	37	37	0	0	0	0.0
	1984	29	28	1	0	0	3.4
Uruguay	1979	91	55	34	2	0	39.5
	1980	27	25	2	0	0	7.4
	1981	8	7	1	0	0	12.5
	1982	39	39	0	0	0	0.0
	1983	62	62	0	0	0	0.0
	1984	73	73	0	0	0	0.0
Yugoslavia	1979	80	76	4	0	0	5.0
	1980	59	53	6	0	0	10.2
	1981	20	20	0	0	0	0.0
	1982	66	66	0	0	0	0.0
	1983	52	52	0	0	0	0.0
	1984	44	44	0	0	0	0.0
Total	1979	2,943	2,496	425	22	0	15.2
	1980	3,158	2,718	421	17	2	13.9
	1981	918	847	66	4	1	7.7
	1982	3,178	2,991	178	9	0	5.9
	1983	3,411	3,330	79	2	0	2.4
	1984	1,766	1,742	23	1	0	1.3

ND = Not detected.

[a]Results for 1984 only reflect period of January through June.
[b]Residues reported on a wet-weight basis.
[c]Limit of detection is 0.01 ppm.

Source: Data supplied by USDA/FSIS.

Appendix F

Modeling Inhalation Exposure and Ground-Water Contamination of Hexachlorobenzene from Landfills

MODELING INHALATION EXPOSURE AND GROUNDWATER CONTAMINATION OF HEXACHLOROBENZENE FROM LANDFILLS

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDES AND TOXIC SUBSTANCES
EXPOSURE EVALUATION DIVISION
Task No. 127
Contract No. 68-02-3968

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Submitted: April 16, 1986

TABLE OF CONTENTS

I. SUMMARY

The atmospheric exposure and groundwater concentrations resulting from hexachlorobenzene in landfills were estimated for several scenarios using appropriate computer simulation models. The scenarios included two sites (Tacoma, Washington and Memphis, Tennessee), two landfill sizes (1/2 acre and 1 acre) and four clay cap thicknesses for the atmospheric exposure simulation (0, 6, 12 and 24 inches). All simulations were performed for a 20-year time period from the time loading to the landfill began.

The maximum concentrations obtained in the groundwater were 1.1×10^{-7} ppm for the Memphis site and 2.7×10^{-6} ppm for the Tacoma site. Both of these concentrations occurred at time equal to 20 yr, and were located at the water table surface directly under the landfill for the one-acre landfill size.

The total inhalation exposures obtained were 8.7 ug/yr for Memphis and 1.3 ug/yr for the Tacoma site, both for the 1-acre, uncapped landfill case.

II. INTRODUCTION

The purpose of this study is to provide modeling results for estimating the exposure from inhalation and concentrations in the groundwater from hexachlorobenzene (HCB) in landfills.

The modeling procedure for estimating inhalation exposure involves three stages. The first stage uses an unsaturated soil zone transport model (SESOIL) to simulate volatilization rates of HCB from the landfill to the atmosphere. The second stage uses an atmospheric model (ISC) to simulate the transport and dispersion of the contaminant in the atmosphere. The third stage uses an inhalation exposure algorithm within the GEMS Atmospheric Modeling Subsystem (GAMS) to estimate the inhalation exposure of HCB.

The modeling procedure for estimating groundwater concentrations involves two stages. The first stage uses the SESOIL model to simulate the vertical transport of HCB from the landfill through the unsaturated soil zones to the groundwater surface. The second stage uses a saturated zone model (AT123D) to simulate the 3-dimensional transport and resulting concentrations of the contaminant in the groundwater.

These modeling simulations are applied over several scenarios which include two sites (Tacoma, Washington and Memphis, Tennessee), two landfill area sizes (1/2 acre and 1 acre) and four clay cap thickness (0, 6, 12, and 24 inches).

III. SESOIL MODEL SIMULATIONS OF VOLATILIZATION RATES AND CONTAMINANT LOADINGS TO GROUNDWATER

SESOIL (Bonozountas and Wagner, 1984) is a seasonal soil compartment model which estimates the rate of chemical transport/transformation within the unsaturated soil zones in terms of mass and concentration distributions among the soil, water and air phases. The model's ability to simulate mass volatilized from a contaminated soil zone is used to simulate volatilization of HCB from landfills. The model's ability to simulate vertical transport/transformation through leaching of the contaminant to the groundwater zone is used to estimate HCB loadings to groundwater.

A. Chemical Data

The Chemical properties used in the SESOIL model are given in Table 1. All chemical data was supplied by Versar, Inc. (1986), with the exception of the diffusion coefficient in air, DA.

The Value of the diffusion coefficient in air was estimated from data for other compounds based on the relationship that the ratio of diffusion coefficients is inversely proportional to the square root of the ratio of molecular weights.

No significant biodegradation nor hydrolysis was assumed to occur in the soil profile.

Table 1. Chemical Data Used in SESOIL Model

Chemical Name	Hexachlorobenzene
Molecular Weight	284.79
Solubility in Water @ 16°C (mg/l)	0.003
Henry's Law Const. (atm -m^3/mole)	1.7×10^{-3}
Diffusion Coefficient in air (cm^2/sec)	0.05
Coefficient of Adsorption on Organic Carbon (ml/g)	1.78×10^4

B. Climatic and Soil Data

The climatic and soil data for each of the two landfill sites (Memphis, TN, and Tacoma, WA) are given in Table 2. All soil data was obtained from the Cities Data Base of the Graphical Exposure Modeling System (GEMS), (GSC, 1984). The soil data used as cover material (clay cap) for the volatilization simulations was a fine generic clay obtained from the Generic Soil Data Option in the Cities Data Base.

An equivalent soil was chosen to represent the sludge layer containing the comtaminant HCB in the landfills. The soil chosen was a default silt loam obtained from the Generic Soil Data option in the Cities Data Base, and its properties are also given in Table 2. No information was available as to the properties of the contaminant sludge.

C. Application Loading and Release Rates

Based on information obtained from Versar, Inc. (1986), each of the two landfill sites have received a total of 12,100 metric tons of industrial sludge during the past ten years. The sludge was assumed to consist of HCB at a concentration of 100 ppm for the Memphis site and 10 ppm for the Tacoma site. Based on an assumed landfill area of 1 acre, the thickness of the contaminant landfill was calculated as 3 meters for both sites. For the Memphis site, the landfill was assumed to exist from the soil surface to a depth of 3 meters. However, due to the shallow groundwater depth at Tacoma (1.5 m), it was assumed that the contaminated material was piled on the land surface to a

Table 2. Soil and Climatic Data Used in SESOIL

Soil Data	Memphis	Tacoma	Sludge Equivalent	Clay Cap
Soil Name	Memphis-Silt Loam	Everett-Gravelly-Sandy-Loam	Silt-Loam (Default)	Clay (Very Fine)
Bulk Density (g/cm^3)	1.35	1.35	1.35	1.35
Intrinsic Permeability (cm^2)	$9.5x10^{-9}$	$8.7x10^{-8}$	$3.5x10^{-10}$	$7.2x10^{-11}$
Disconnectedness Index	5.5	6.0	5.5	12.0
Effective Porosity	0.35	0.25	0.35	0.20
Organic Carbon Content (%)	1.0	1.0	3.0	3.0
Groundwater Depth (m)	10.0	1.5	N/A	N/A
Climatic Data				
Annual Precipitation (cm)	124	96		
Annual Mean Temp. (^oc)	16.5	10.6		
Annual Mean Rel. Hum. (%)	56.7	62.3		
Annual Mean Cloud Cover	0.56	0.68		
Annual Mean Shortwave Albedo	0.18	0.16		
Latitude (^oN)	35.1	47.4		

height of 3 meters. For the 1/2 acre size landfills the same HCB concentrations and landfill thickness were used, however half of the total sludge mass was assumed to be contained in the landfills.

The contaminant zone release rates used for the volatilization simulations were calculated as the product of solubility of HCB in water and the moisture infiltration rate into the comtaminant zone. For the Memphis site, the average release used was 0.031 ug/cm^2/month; and for the Tacoma site, an average release of 0.025 ug/cm^2/month was used.

For simulation of loadings to groundwater, it was assumed that all HCB mass could be leached through the soil zones in both dissolved and undissolved states. Thus, the entire mass of HCB applied to the landfills over the 10 year disposal period was used as the release rate. The release rates used were 252 and 25.2 ug/cm^2/month for the Memphis and Tacoma sites, respectively.

D. SESOIL Modeling Results

All SESOIL simulations were performed over a 20-year simulation time period, beginning from the time the loading of HCB was first applied to the landfills.

For volatilization estimates, a total of 16 model runs were performed for all combinations of the two sites (Memphis and Tacoma), two landfill sizes (1/2 and 1 acre), and four clay cover thicknesses (0, 6, 12 and 24 inch). The maximum volatilization rate is assumed to

occur when the concentration of HCB in the soil moisture equals the solubility of HCB in water. In all cases, this occurred within the first two years and remained at this limit for the remainder of the simulation period. The maximum volatilization emission rates for the eight cases are given in Table 3.

For estimation of contaminant loadings to groundwater, an additional four SESOIL model runs were performed for all combinations of the two sites and two landfill sizes. The soil profile for these simulations consisted of uncapped soil (0-inch clay cap). The release of HCB in the contaminated zone (landfill zone) was applied to the first ten years of simulation, and zero release during years 11 through 20. The resulting mass loadings to groundwater are given in Table 4. It should be noted that steady state had not been attained after 20 years, and higher mass loading rates to groundwater would be expected for longer simulation periods.

Table 3. Maximum HCB Volatilization from Soil Surface (ug/yr)

Clay Cap Thickness (inches)	Memphis		Tacoma	
	1/2 acre	1 acre	1/2 acre	1 acre
0	3.26×10^{5}	6.52×10^{5}	4.26×10^{4}	8.51×10^{4}
6	3.61×10^{4}	7.21×10^{4}	1.52×10^{4}	3.04×10^{4}
12	3.45×10^{4}	6.89×10^{4}	1.45×10^{4}	2.90×10^{4}
24	3.14×10^{4}	6.28×10^{4}	1.32×10^{4}	2.64×10^{4}

Table 4. HCB Loadings to Groundwater (ug/yr)

Year	Memphis		Tacoma	
	1/2 acre	1 acre	1/2 acre	1 acre
1	0	0	0	0
2	0	0	0	0
3	0	0	14.4	28.8
4	0	0	80.1	160
5	20.6	41	225	450
6	78.8	158	472	944
7	187	374	846	1,690
8	353	706	1,370	2,740
9	576	1,150	2,070	4,140
10	866	1,730	2,960	5,930
11	1,240	2,480	4,080	8,150
12	1,700	3,400	5,430	10,900
13	2,240	4,470	7,010	14,000
14	2,850	5,710	8,810	17,600
15	3,550	7,100	10,900	21,800
16	4,330	8,660	13,100	26,200
17	5,190	10,400	15,600	31,200
18	6,120	12,200	18,300	36,600
19	7,150	14,300	21,200	42,500
20	8,250	16,500	24,400	48,800

IV. AT123D MODEL SIMULATIONS OF GROUNDWATER CONCENTRATIONS

AT123D (Yeh, 1981) is a generalized analytical transient one-, two-, and/or three dimensional computer model designed for estimating the rate of pollutant transport/transformation in a groundwater system. It accounts for various transport and transformation processes in the groundwater system which include advection, dispersion, and adsorption. The model produces output in the form of spacial distributions of the comtaminant concentrations at selected time intervals.

A. Groundwater Data

The aquifer data used by AT123D for the two sites are given in Table 5. Values of soil porosity, hydraulic conductivity, hydraulic gradient and bulk density were obtained from the GRNDWAT data base (Versar, Inc., 1984) available in GEMS (GSC, 1984). The value chosen for each of those parameters was the mean of the four measured values provided in GRNDWAT. The dispersion coefficients were estimated from measured values for similar soils as given by Anderson (1979). The adsorption coefficient on soil was estimated from the assumption that the aquifer soil consists of 0.1% organic carbon.

B. AT123D Modeling Results

A total of four AT123D model simulations were performed for combinations of the two sites and two landfill areas. The mass-to-groundwater loading distributions as calculated by SESOIL were used as

Table 5. Groundwater Data Used in AT123D

	Memphis	Tacoma
Soil Porosity (-)	0.30	0.35
Hydraulic Conductivity (m^3/hr)	0.75	23.0
Hydraulic Gradient (m/m)	3.0×10^{-3}	1.4×10^{-6}
Soil Bulk Density (kg/m^3)	1850	1790
Longitudinal Dispersion Coeff. (m)	30	30
Lateral Dispersion Coeff. (m)	10	10
Vertical Dispersion Coeff. (m)	10	10
Adsorption Coefficient (m^3/kg)	1.78×10^{-2}	1.78×10^{-2}

input loadings for AT123D for the 20-year simulation period. In all cases, the maximum concentrations in the groundwater were obtained at year 20 at the water table surface, and the results are given in Table 6. It should be noted that steady state had not been attained by year 20, and higher concentrations in groundwater would be expected for longer simulation periods.

Table 6. HCB Concentrations inGroundwater at Water Table Surface along Plume Centerline at Year 20 (ppm)

Horizontal Distance from Center of Landfill	Memphis		Tacoma	
	1/2 acre	1 acre	1/2 acre	1 acre
0	$1.1x10^{-7}$	$1.1x10^{-7}$	$2.7x10^{-6}$	$2.7x10^{-6}$
20	$7.7x10^{-8}$	$1.0x10^{-7}$	$2.6x10^{-6}$	$2.7x10^{-6}$
40	$6.0x10^{-9}$	$2.0x10^{-8}$	0.0	$5.1x10^{-11}$
60	$4.3x10^{-10}$	$1.5x10^{-9}$	0.0	0.0
80	$2.2x10^{-11}$	$9.5x10^{-11}$	0.0	0.0
100	$7.3x10^{-13}$	$3.9x10^{-12}$	0.0	0.0
120	$1.5x10^{-14}$	$1.0x10^{-13}$	0.0	0.0
140	$1.8x10^{-15}$	$1.6x10^{-15}$	0.0	0.0
160	$4.4x10^{-19}$	$1.2x10^{-17}$	0.0	0.0
180	0.0	0.0	0.0	0.0

V. ISC ATMOSPHERIC MODELING

The OTS Graphical Exposure Modeling System (GEMS) Atmospheric Modeling Subsystem (GAMS) and the GAMS INterface (GAMSIN) were used to conduct and set up the atmospheric modeling. The Industrial Source Complex (ISC) long-term model was used to estimate annual average ground-level atmospheric concentrations due to the volatilized HCB. ISC was developed by Bowers et al. (1980) for the Source Receptor Analysis Branch, Office Air Quality Planning and Standards, U.S. Environmental Protection Agency.

The modeling was conducted using the area source algorithm of ISC. The area source equation in ISC is based on the equation for a continuous and finite crosswind line source. Annual average STAR data (frequencies of occurrence of wind direction versus wind speed for each atmospheric stability) and auxiliary climatological files were accessed by GAMSIN to supply required data to the ISC input data files. Summaries of the climatological and STAR data used are given in Tables 7-A and B.

The estimated values for mass volatilized presented in Table 3, were converted into units of (g s^{-1} m^{-2}) and used for input into the ISC model. The modeling scenarios consisted of two area sizes (one-half acre and one acre) and four clay cap thicknesses (0, 6, 12, and 24 inches).

Table 7-A. Climatological and STAR Data Summaries for Memphis, TN.

STAR STATION 0143 MEMPHIS TN ANNUAL 1967-1971

DIRECTION	FREQUENCY	WINDSPEED	DIRECTION	FREQUENCY	WINDSPEED
N	0.07196	4.76	S	0.13630	4.38
NNE	0.05090	4.42	SSW	0.07469	4.61
NE	0.05936	3.89	SW	0.07632	4.29
ENE	0.05203	3.09	WSW	0.04997	4.14
E	0.08439	2.65	W	0.05156	3.77
ESE	0.03948	3.09	WNW	0.03991	4.48
SE	0.06345	3.68	NW	0.03784	5.15
SSE	0.07883	3.82	NNW	0.03307	4.97

STABILITY	FREQUENCY	WINDSPEED
1	0.00763	1.84
2	0.06174	2.75
3	0.11541	4.12
4	0.47379	5.41
5	0.13936	3.61
6	0.20213	1.59

AUXILIARY VARIABLES		
Afternoon mixing height	(meters)	150
Nocturnal mixing height	(meters)	45
Average air temperature	(Kelvin)	288.6
Avg maximum temperature	(Kelvin)	292.3
Avg minimum temperature	(Kelvin)	284.9
Precipitation frequency	(percent)	5.9
Precipitation intensity	(mm/hour)	2.7
Grand average windspeed	(m/s)	4.1

Table 7-B. Climatological and STAR Data Summaries for Tacoma, WA.

STAR STATION 0365 SEATTLE/TACOMA WA ANNUAL 1948-1953

DIRECTION	FREQUENCY	WINDSPEED	DIRECTION	FREQUENCY	WINDSPEED
N	0.07793	4.44	S	0.07346	4.56
NNE	0.08441	4.33	SSW	0.13943	5.48
NE	0.06295	3.87	SW	0.12933	6.00
ENE	0.02240	3.01	WSW	0.05977	4.84
E	0.03687	2.58	W	0.02584	3.58
ESE	0.05848	3.34	WNW	0.02859	2.88
SE	0.07744	3.18	NW	0.02496	3.30
SSE	0.05622	3.55	NNW	0.04194	3.96

STABILITY	FREQUENCY	WINDSPEED
1	0.00556	1.07
2	0.03948	2.05
3	0.08725	3.46
4	0.66482	5.25
5	0.08373	3.74
6	0.11918	1.31

AUXILIARY VARIABLES		
Afternoon mixing height	(meters)	1266.0
Nocturnal mixing height	(meters)	611.0
Average air temperature	(Kelvin)	279.5
Avg maximum temperature	(Kelvin)	283.2
Avg minimum temperature	(Kelvin)	276.0
Precipitation frequency	(percent)	11.5
Precipitation intensity	(mm/hour)	1.2
Grand average windspeed	(m/s)	4.3

ISC is implemented in GAMS to estimate annual average concentrations around each source on a polar coordinate system. The coordinate system is divided into 16 sectors, each of which is 22.5 degrees and centered on the subcardinal compass point directions which match those of the annual STability ARray (STAR) climatological data utilized by ISC, and 10 default radial distances or concentric rings at 0.5, 1, 2, 3, 4, 5, 10, 15, 25 and 50 kilometers from the source.

Intra-ring concentration estimates are calculated at three points along the centerline of each sector segment. The term "sector segment" is used to discuss a given sector (wind direction) and distance interval (ring distance interval). The average concentration for each sector segment (a total of 160) is obtained by calculating the average of the intra-ring concentration estimates including both end point concentration estimates for each sector segment.

The maximum annual average intra-ring concentration estimates for the two locations, two land areas, and the four clay cap thickness are presented in Table 8. The distances listed are the off fence line distances corresponding to the intra-ring distance where the maximum estimate occurred. In all cases the maximums occurred at the first intra-ring distance of 166.7 m.

Table 8. Maximum Annual Average Intra-ring Concentrations (ug/m^3)

Memphis, TN

Cap (in)	1/2 Acre 141m Distance	1 Acre 130m Distance
0	1.01×10^{-6}	1.74×10^{-6}
6	1.11×10^{-7}	1.92×10^{-7}
12	1.06×10^{-7}	1.84×10^{-7}
24	9.72×10^{-8}	1.68×10^{-7}

Tacoma, WA

Cap (in)	1/2 Acre 141m Distance	1 Acre 130m Distance
0	1.00×10^{-7}	1.78×10^{-7}
6	3.58×10^{-8}	6.34×10^{-8}
12	3.42×10^{-8}	6.05×10^{-8}
24	3.12×10^{-8}	5.52×10^{-8}

VI. INHALATION EXPOSURE ESTIMATION

Inhalation exposure calculations are performed by GAMS for each sector segment population and across all sector segments around a source. The annual average inhalation exposure for a sector segment is estimated using the following expression:

$$INHALEXPO(i) = CONC(i)*POP(i)*IVR$$

where,

(i) = index for a given sector segment

INHALEXPO(i) = annual average inhalation exposure (ug yr^{-1})

CONC(i) = annual average concentration (ug m^{-3})

POP(i) = exposed population (persons)

IVR = annual inhalation volume rate (m^3 $yr^{-1}$$person^{-1}$)

The annual inhalation volume rate is the product of the daily inhalation volume rate (default value of 22.0 cubic meters per day per person) and 365 days per year. The default inhalation volume rate is the average of the adult man (2.3×10^4 l/day) and adult woman (2.1×10^4 l/day) breathing rates given by Synder, et al. (1974).

Tables of cumulative population exposed and cumulative inhalation exposure by concentration level are generated from the sector segment results by GAMS. The tables range from the maximum sector segment average concentration to the minimum by order of magnitude steps. The cumulative population exposed and inhalation exposure results for the one acre, 0 inch cap scenario for Memphis and Tacoma are presented in

Tables 9 and 10 respectively. A complete listing of the 160 sector segment results (10 ring distances by 16 directions) and the cumulative tables for all modeling scenarios is given in Appendix A.

Table 9. 50 Kilometer Cumulative Population Exposed and Inhalation Exposure to HCB around Memphis, TN. One Acre, 0 Inch Cap Scenario

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE INHALATION EXPOSURE (UG/YR)	(%)
9.193E-07	0	0.00	0.000E+00	0.00
1.000E-07	0	0.00	0.000E+00	0.00
1.000E-08	5895	0.64	8.211E-01	9.40
1.000E-09	277148	29.94	6.543E+00	74.90
1.000E-10	904417	97.72	8.724E+00	99.86
5.540E-11	925566	100.00	8.736E+00	100.00

Table 10. 50 Kilometer Cumulative Population Exposed and Inhalation Exposure to HCB around Tacoma, WA. One Acre, 0 Inch Cap Scenario

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE INHALATION EXPOSURE (UG/YR)	(%)
9.136E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	4958	0.28	8.094E-02	6.36
1.000E-10	319902	17.90	8.139E-01	63.99
1.000E-11	1762216	98.61	1.270E+00	99.85
8.462E-12	1787083	100.00	1.272E+00	100.00

VII. REFERENCES

Anderson, M.P. 1979. "Using Models to Simulate the Movement of Contaminants through Groundwater Flow Systems", CRC-Critical Reviews in Environmental Control.

Bonazountas, M. and J.M. Wagner. 1984. SESOIL - A seasonal soil compartment Model. Arthur D. Little Inc. Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Bowers, J.F., et al., 1980. Industrial Source Complex (ISC) Dispersion Model User's Guide (Volume I), PB80-133044, U.S. Environmental Protection Agency, Office Air Quality Planning and Standards, Research Triangle Park, N.C.

GSC. 1984. User's Guide to the Graphical Exposure Modeling System (GEMS). Draft Report. General Software Corporation, Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. Contract No. 68016618.

Synder W.S., Cook M.J., Nasset E.S. et al., 1974. Report of the task group on reference man. International commission on radiological protection No. 23. New York: Permagon Press.

Versar, Inc. 1984. "Creation of Groundwater Model Parameter Files". Versar, Inc., Washington, D.C.: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

Versar, Inc. 1986. Personal Communication. Springfield, Va.

Yeh, G.T. 1981. "AT123D: Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System", ORNL-Oak Ridge National Labortory, Oak Ridge, TN.

APPENDIX A. SECTOR SEGMENT AND CUMULATIVE RESULTS FOR ALL ATMOSPHERIC MODELING SCENARIOS

MEMPHIS SCENARIO
POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; one acre EMISSION TYPE ; cap0
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	8.129E-07	1.783E-07	5.745E-08	2.308E-08	1.338E-08	9.059E-09	4.695E-09	2.023E-09	1.049E-09	4.547E-10
		0	0	0	0	0	0	0	4184	675	3439
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.798E-02	5.686E-03	1.256E-02
NNE	22.5	6.071E-07	1.108E-07	3.154E-08	1.160E-08	6.450E-09	4.256E-09	2.143E-09	8.917E-10	4.544E-10	1.942E-10
		0	0	0	0	0	0	10095	7971	2614	11151
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.737E-01	5.707E-02	9.538E-03	1.739E-02
NE	45.0	4.886E-07	1.005E-07	3.159E-08	1.247E-08	7.168E-09	4.826E-09	2.484E-09	1.062E-09	5.479E-10	2.366E-10
		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	3.584E-02	3.913E-01	2.414E-01	2.623E-01	2.248E-01	8.320E-02	6.017E-02
ENE	67.5	4.305E-07	8.189E-08	2.401E-08	9.016E-09	5.070E-09	3.371E-09	1.712E-09	7.218E-10	3.709E-10	1.598E-10
		0	0	831	2696	4386	3344	33197	27817	45276	10836
		0.000E+00	0.000E+00	1.602E-01	1.952E-01	1.786E-01	9.052E-02	4.564E-01	1.612E-01	1.349E-01	1.391E-02
E	90.0	3.876E-07	8.186E-08	2.586E-08	1.023E-08	5.901E-09	3.982E-09	2.057E-09	8.851E-10	4.596E-10	1.996E-10
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	5.461E-02	3.978E-02	1.172E-01	1.763E-01	4.222E-01	2.639E-01	1.243E-01	2.561E-02
ESE	112.5	2.927E-07	5.654E-08	1.680E-08	6.383E-09	3.604E-09	2.400E-09	1.219E-09	5.129E-10	2.623E-10	1.122E-10
		0	0	1834	5115	5592	3585	38084	42248	88358	18498
		0.000E+00	0.000E+00	2.475E-01	2.622E-01	1.618E-01	6.908E-02	3.729E-01	1.740E-01	1.861E-01	1.667E-02
SE	135.0	2.071E-07	3.904E-08	1.173E-08	4.487E-09	2.535E-09	1.688E-09	8.568E-10	3.599E-10	1.839E-10	7.857E-11
		0	0	161	3310	6031	7377	21652	13437	17612	12881
		0.000E+00	0.000E+00	1.516E-02	1.193E-01	1.228E-01	9.997E-02	1.490E-01	3.883E-02	2.601E-02	8.127E-03
SSE	157.5	2.251E-07	3.887E-08	1.064E-08	3.785E-09	2.057E-09	1.335E-09	6.575E-10	2.653E-10	1.327E-10	5.540E-11
		0	0	38	1644	3882	5607	12087	33116	28901	8268
		0.000E+00	0.000E+00	3.247E-03	4.997E-02	6.412E-02	6.012E-02	6.382E-02	7.056E-02	3.079E-02	3.678E-03
S	180.0	3.260E-07	7.098E-08	2.285E-08	9.167E-09	5.292E-09	3.567E-09	1.836E-09	7.835E-10	4.033E-10	1.732E-10
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	7.803E-02	7.037E-02	1.395E-01	1.642E-01	2.626E-01	3.083E-02	1.233E-02
SSW	202.5	3.817E-07	7.136E-08	2.076E-08	7.763E-09	4.348E-09	2.882E-09	1.458E-09	6.105E-10	3.121E-10	1.336E-10
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.249E-02	5.757E-03	4.611E-03
SW	225.0	4.977E-07	9.802E-08	3.011E-08	1.171E-08	6.693E-09	4.494E-09	2.308E-09	9.846E-10	5.082E-10	2.193E-10
		0	0	0	0	0	0	20	0	4	1583
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.706E-04	0.000E+00	1.632E-05	2.788E-03
WSW	247.5	7.502E-07	1.455E-07	4.304E-08	1.629E-08	9.224E-09	6.167E-09	3.155E-09	1.342E-09	6.929E-10	2.996E-10
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.312E-05	1.046E-02	7.195E-03
W	270.0	9.193E-07	2.136E-07	7.111E-08	2.915E-08	1.712E-08	1.169E-08	6.121E-09	2.675E-09	1.398E-09	6.101E-10

		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.648E-01	0.000E+00	5.950E-01	2.094E-01	1.118E-02	8.692E-03
WNW	292.5	6.963E-07	1.234E-07	3.446E-08	1.246E-08	6.902E-09	4.552E-09	2.294E-09	9.582E-10	4.904E-10	2.103E-10
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.270E-02	3.189E-02	7.301E-03	1.484E-02
NW	315.0	6.373E-07	1.249E-07	3.840E-08	1.495E-08	8.561E-09	5.760E-09	2.966E-09	1.270E-09	6.565E-10	2.838E-10
		0	0	0	0	0	0	0	3246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.290E-02	0.000E+00	6.368E-03
NNW	337.5	7.900E-07	1.610E-07	4.942E-08	1.923E-08	1.103E-08	7.421E-09	3.826E-09	1.641E-09	8.503E-10	3.685E-10
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.583E-03	4.384E-03	9.058E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap0 EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
9.193E-07	0	0.00	0.000E+00	0.00
1.000E-07	0	0.00	0.000E+00	0.00
1.000E-08	5895	0.64	8.211E-01	9.40
1.000E-09	277148	29.94	6.543E+00	74.90
1.000E-10	904417	97.72	8.724E+00	99.86
5.540E-11	925566	100.00	8.736E+00	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; one acre EMISSION TYPE ; cap6
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
@ POPULATION EXPOSURE (UG/YR)
@ POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	8.972E-08	1.968E-08	6.340E-09	2.547E-09	1.477E-09	9.998E-10	5.182E-10	2.233E-10	1.158E-10	5.019E-11
		0	0	0	0	0	0	0	4184	675	3439
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.503E-03	6.275E-04	1.386E-03
NNE	22.5	6.701E-08	1.223E-08	3.482E-09	1.281E-09	7.118E-10	4.697E-10	2.365E-10	9.842E-11	5.015E-11	2.143E-11
		0	0	0	0	0	0	10095	7971	2614	11151
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.917E-02	6.299E-03	1.053E-03	1.919E-03
NE	45.0	5.393E-08	1.109E-08	3.487E-09	1.376E-09	7.912E-10	5.326E-10	2.742E-10	1.172E-10	6.048E-11	2.612E-11
		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	3.956E-03	4.319E-02	2.665E-02	2.895E-02	2.481E-02	9.182E-03	6.641E-03
ENE	67.5	4.752E-08	9.038E-09	2.650E-09	9.951E-10	5.596E-10	3.721E-10	1.890E-10	7.967E-11	4.094E-11	1.764E-11
		0	0	831	2696	4386	3344	33197	27817	45276	10836
		0.000E+00	0.000E+00	1.768E-02	2.154E-02	1.971E-02	9.990E-03	5.037E-02	1.780E-02	1.489E-02	1.535E-03

E	90.0	4.278E-08	9.035E-09	2.854E-09	1.130E-09	6.513E-10	4.395E-10	2.270E-10	9.769E-11	5.072E-11	2.204E-11
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	6.027E-03	4.390E-03	1.293E-02	1.945E-02	4.660E-02	2.913E-02	1.372E-02	2.826E-03
ESE	112.5	3.230E-08	6.241E-09	1.855E-09	7.045E-10	3.977E-10	2.648E-10	1.346E-10	5.661E-11	2.895E-11	1.238E-11
		0	0	1834	5115	5592	3585	38084	42248	88358	18498
		0.000E+00	0.000E+00	2.732E-02	2.894E-02	1.786E-02	7.624E-03	4.116E-02	1.920E-02	2.054E-02	1.839E-03
SE	135.0	2.286E-08	4.309E-09	1.294E-09	4.952E-10	2.798E-10	1.863E-10	9.457E-11	3.972E-11	2.030E-11	8.672E-12
		0	0	161	3310	6031	7377	21652	13437	17612	12881
		0.000E+00	0.000E+00	1.673E-03	1.316E-02	1.355E-02	1.103E-02	1.644E-02	4.286E-03	2.871E-03	8.970E-04
SSE	157.5	2.484E-08	4.290E-09	1.174E-09	4.177E-10	2.270E-10	1.474E-10	7.257E-11	2.929E-11	1.464E-11	6.114E-12
		0	0	38	1644	3882	5607	12087	33116	28901	8268
		0.000E+00	0.000E+00	3.584E-04	5.515E-03	7.077E-03	6.635E-03	7.043E-03	7.788E-03	3.398E-03	4.059E-04
S	180.0	3.599E-08	7.834E-09	2.522E-09	1.012E-09	5.841E-10	3.936E-10	2.027E-10	8.648E-11	4.451E-11	1.912E-11
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	8.612E-03	7.767E-03	1.539E-02	1.812E-02	2.898E-02	3.403E-03	1.360E-03
SSW	202.5	4.213E-08	7.877E-09	2.291E-09	8.568E-10	4.799E-10	3.181E-10	1.609E-10	6.739E-11	3.445E-11	1.474E-11
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.689E-03	6.354E-04	5.089E-04
SW	225.0	5.493E-08	1.082E-08	3.324E-09	1.292E-09	7.387E-10	4.960E-10	2.547E-10	1.087E-10	5.609E-11	2.421E-11
		0	0	0	0	0	0	20	0	4	1583
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.091E-05	0.000E+00	1.802E-06	3.077E-04
WSW	247.5	8.280E-08	1.606E-08	4.751E-09	1.798E-09	1.018E-09	6.806E-10	3.483E-10	1.482E-10	7.648E-11	3.306E-11
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.759E-06	1.154E-03	7.941E-04
W	270.0	1.015E-07	2.357E-08	7.848E-09	3.218E-09	1.890E-09	1.290E-09	6.756E-10	2.952E-10	1.543E-10	6.734E-11
		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.923E-02	0.000E+00	6.567E-02	2.311E-02	1.234E-03	9.593E-04
WNW	292.5	7.686E-08	1.362E-08	3.804E-09	1.376E-09	7.617E-10	5.024E-10	2.532E-10	1.058E-10	5.413E-11	2.321E-11
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.712E-03	3.519E-03	8.058E-04	1.638E-03
NW	315.0	7.034E-08	1.379E-08	4.238E-09	1.650E-09	9.449E-10	6.357E-10	3.273E-10	1.402E-10	7.246E-11	3.133E-11
		0	0	0	0	0	0	0	2246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.528E-03	0.000E+00	7.029E-04
NNW	337.5	8.719E-08	1.777E-08	5.454E-09	2.123E-09	1.217E-09	8.191E-10	4.223E-10	1.812E-10	9.385E-11	4.067E-11
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.851E-04	4.838E-04	9.997E-04

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM capG EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
1.015E-07	0	0.00	0.000E+00	0.00
1.000E-07	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00

1.000E-09	6955	0.75	9.924E-02	10.29
1.000E-10	281292	30.39	7.257E-01	75.26
1.000E-11	904417	97.72	9.629E-01	99.86
6.114E-12	925566	100.00	9.642E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; one acre EMISSION TYPE ; csp12
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION x POPULATION x ANNUAL BREATHING RATE(22.0M3/DAY x 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	8.575E-08	1.881E-08	6.059E-09	2.434E-09	1.412E-09	9.555E-10	4.953E-10	2.134E-10	1.106E-10	4.796E-11
		0	0	0	0	0	0	0	4184	675	3439
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.171E-03	5.997E-04	1.324E-03
NNE	22.5	6.404E-08	1.168E-08	3.327E-09	1.224E-09	6.803E-10	4.489E-10	2.261E-10	9.405E-11	4.793E-11	2.048E-11
		0	0	0	0	0	0	10095	7971	2614	11151
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.832E-02	6.020E-03	1.006E-03	1.834E-03
NE	45.0	5.154E-08	1.060E-08	3.332E-09	1.315E-09	7.561E-10	5.090E-10	2.620E-10	1.120E-10	5.780E-11	2.496E-11
		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	3.781E-03	4.127E-02	2.546E-02	2.766E-02	2.371E-02	8.775E-03	6.347E-03
ENE	67.5	4.541E-08	8.638E-09	2.533E-09	9.510E-10	5.348E-10	3.556E-10	1.806E-10	7.614E-11	3.913E-11	1.686E-11
		0	0	831	2696	4386	3344	33197	27817	45276	10836
		0.000E+00	0.000E+00	1.690E-02	2.059E-02	1.884E-02	9.548E-03	4.814E-02	1.701E-02	1.423E-02	1.467E-03
E	90.0	4.088E-08	8.634E-09	2.728E-09	1.080E-09	6.225E-10	4.200E-10	2.170E-10	9.336E-11	4.848E-11	2.106E-11
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	5.760E-03	4.196E-03	1.236E-02	1.859E-02	4.453E-02	2.784E-02	1.311E-02	2.701E-03
ESE	112.5	3.087E-08	5.964E-09	1.773E-09	6.733E-10	3.801E-10	2.531E-10	1.286E-10	5.410E-11	2.767E-11	1.183E-11
		0	0	1834	5115	5592	3585	38084	42248	88358	18498
		0.000E+00	0.000E+00	2.610E-02	2.765E-02	1.707E-02	7.286E-03	3.934E-02	1.835E-02	1.963E-02	1.758E-03
SE	135.0	2.185E-08	4.118E-09	1.237E-09	4.733E-10	2.674E-10	1.780E-10	9.037E-11	3.796E-11	1.940E-11	8.288E-12
		0	0	161	3310	6031	7377	21652	13437	17612	12881
		0.000E+00	0.000E+00	1.599E-03	1.258E-02	1.295E-02	1.054E-02	1.571E-02	4.096E-03	2.744E-03	8.572E-04
SSE	157.5	2.374E-08	4.100E-09	1.122E-09	3.992E-10	2.170E-10	1.408E-10	6.935E-11	2.799E-11	1.399E-11	5.843E-12
		0	0	38	1644	3882	5607	12087	33116	28901	8268
		0.000E+00	0.000E+00	3.425E-04	5.270E-03	6.763E-03	6.341E-03	6.731E-03	7.443E-03	3.248E-03	3.879E-04
S	180.0	3.439E-08	7.487E-09	2.410E-09	9.670E-10	5.582E-10	3.762E-10	1.937E-10	8.265E-11	4.254E-11	1.827E-11
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	8.231E-03	7.423E-03	1.471E-02	1.732E-02	2.769E-02	3.252E-03	1.300E-03
SSW	202.5	4.027E-08	7.528E-09	2.189E-09	8.188E-10	4.587E-10	3.040E-10	1.538E-10	6.440E-11	3.292E-11	1.409E-11
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.481E-03	6.072E-04	4.863E-04
SW	225.0	5.249E-08	1.034E-08	3.176E-09	1.235E-09	7.059E-10	4.740E-10	2.434E-10	1.039E-10	5.360E-11	2.313E-11
		0	0	0	0	0	0	20	0	4	1583

		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.910E-05	0.000E+00	1.722E-06	2.940E-04
WSW	247.5	7.913E-08	1.534E-08	4.540E-09	1.718E-09	9.730E-10	6.505E-10	3.328E-10	1.416E-10	7.309E-11	3.160E-11
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.548E-06	1.103E-03	7.589E-04
W	270.0	9.697E-08	2.253E-08	7.501E-09	3.075E-09	1.806E-09	1.233E-09	6.457E-10	2.821E-10	1.475E-10	6.436E-11
		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.793E-02	0.000E+00	6.276E-02	2.209E-02	1.179E-03	9.168E-04
WNW	292.5	7.345E-08	1.302E-08	3.635E-09	1.315E-09	7.280E-10	4.802E-10	2.420E-10	1.011E-10	5.173E-11	2.218E-11
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.504E-03	3.363E-03	7.701E-04	1.566E-03
NW	315.0	6.722E-08	1.318E-08	4.051E-09	1.577E-09	9.030E-10	6.075E-10	3.128E-10	1.340E-10	6.925E-11	2.994E-11
		0	0	0	0	0	0	0	2246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.416E-03	0.000E+00	6.717E-04
NNW	337.5	8.333E-08	1.698E-08	5.212E-09	2.029E-09	1.163E-09	7.828E-10	4.036E-10	1.731E-10	8.969E-11	3.887E-11
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.725E-04	4.624E-04	9.554E-04

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap12 EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
9.697E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	5895	0.64	8.661E-02	9.40
1.000E-10	281292	30.39	6.935E-01	75.26
1.000E-11	904417	97.72	9.202E-01	99.86
5.843E-12	925566	100.00	9.215E-01	100.00

* CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; one acre EMISSION TYPE ; cap24
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION * POPULATION * ANNUAL BREATHING RATE(22.0M3/DAY * 365. DAYS/YR)

DISTANCES (KM) :	0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR MID-ANGLE										
N 0.0	7.827E-08	1.717E-08	5.531E-09	2.222E-09	1.289E-09	8.722E-10	4.521E-10	1.948E-10	1.010E-10	4.378E-11
	0	0	0	0	0	0	0	4184	675	3439
	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.545E-03	5.474E-04	1.209E-03
NNE 22.5	5.846E-08	1.067E-08	3.037E-09	1.117E-09	6.210E-10	4.098E-10	2.063E-10	8.585E-11	4.375E-11	1.869E-11
	0	0	0	0	0	0	10095	7971	2614	11151
	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.673E-02	5.495E-03	9.183E-04	1.674E-03
NE 45.0	4.704E-08	9.678E-09	3.042E-09	1.200E-09	6.902E-10	4.646E-10	2.392E-10	1.022E-10	5.276E-11	2.278E-11

		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	3.451E-03	3.767E-02	2.324E-02	2.525E-02	2.165E-02	8.010E-03	5.794E-03
ENE	67.5	4.145E-08	7.884E-09	2.312E-09	8.680E-10	4.882E-10	3.246E-10	1.648E-10	6.950E-11	3.572E-11	1.539E-11
		0	0	831	2696	4386	3344	33197	27817	45276	10836
		0.000E+00	0.000E+00	1.543E-02	1.879E-02	1.719E-02	8.715E-03	4.394E-02	1.552E-02	1.298E-02	1.339E-03
E	90.0	3.731E-08	7.881E-09	2.490E-09	9.854E-10	5.682E-10	3.834E-10	1.981E-10	8.522E-11	4.425E-11	1.922E-11
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	5.258E-03	3.830E-03	1.128E-02	1.697E-02	4.065E-02	2.541E-02	1.197E-02	2.465E-03
ESE	112.5	2.818E-08	5.444E-09	1.618E-09	6.146E-10	3.470E-10	2.310E-10	1.174E-10	4.938E-11	2.526E-11	1.080E-11
		0	0	1834	5115	5592	3585	38084	42148	88358	18498
		0.000E+00	0.000E+00	2.383E-02	2.524E-02	1.558E-02	6.651E-03	3.591E-02	1.675E-02	1.792E-02	1.605E-03
SE	135.0	1.994E-08	3.759E-09	1.129E-09	4.320E-10	2.441E-10	1.625E-10	8.249E-11	3.465E-11	1.771E-11	7.565E-12
		0	0	161	3310	6031	7377	21652	13437	17612	13881
		0.000E+00	0.000E+00	1.460E-03	1.148E-02	1.182E-02	9.625E-03	1.434E-02	3.739E-03	2.505E-03	7.825E-04
SSE	157.5	2.167E-08	3.742E-09	1.025E-09	3.644E-10	1.980E-10	1.286E-10	6.331E-11	2.555E-11	1.277E-11	5.334E-12
		0	0	38	1644	3882	5607	12087	33116	28901	8268
		0.000E+00	0.000E+00	3.126E-04	4.811E-03	6.174E-03	5.788E-03	6.144E-03	6.794E-03	2.965E-03	3.541E-04
S	180.0	3.139E-08	6.834E-09	2.200E-09	8.827E-10	5.095E-10	3.434E-10	1.768E-10	7.544E-11	3.803E-11	1.668E-11
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	7.513E-03	6.775E-03	1.343E-02	1.581E-02	2.528E-02	2.969E-03	1.187E-03
SSW	202.5	3.675E-08	6.871E-09	1.999E-09	7.474E-10	4.187E-10	2.775E-10	1.404E-10	5.878E-11	3.005E-11	1.286E-11
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.091E-03	5.543E-04	4.439E-04
SW	225.0	4.792E-08	9.438E-09	2.899E-09	1.127E-09	6.444E-10	4.326E-10	2.222E-10	9.480E-11	4.893E-11	2.112E-11
		0	0	0	0	0	0	20	0	4	1583
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.569E-05	0.000E+00	1.572E-06	2.684E-04
WSW	247.5	7.223E-08	1.401E-08	4.144E-09	1.568E-09	8.881E-10	5.938E-10	3.038E-10	1.293E-10	6.672E-11	2.884E-11
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.152E-06	1.007E-03	6.927E-04
W	270.0	8.851E-08	2.056E-08	6.847E-09	2.807E-09	1.648E-09	1.125E-09	5.894E-10	2.575E-10	1.346E-10	5.875E-11
		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.549E-02	0.000E+00	5.728E-02	2.016E-02	1.076E-03	8.368E-04
WNW	292.5	6.704E-08	1.188E-08	3.318E-09	1.200E-09	6.645E-10	4.383E-10	2.309E-10	9.226E-11	4.722E-11	2.025E-11
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.111E-03	3.070E-03	7.029E-04	1.429E-03
NW	315.0	6.136E-08	1.203E-08	3.697E-09	1.439E-09	8.243E-10	5.546E-10	2.855E-10	1.223E-10	6.321E-11	2.733E-11
		0	0	0	0	0	0	0	2246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.205E-03	0.000E+00	6.132E-04
NNW	337.5	7.606E-08	1.550E-08	4.758E-09	1.852E-09	1.062E-09	7.145E-10	3.684E-10	1.580E-10	8.187E-11	3.548E-11
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.487E-04	4.331E-04	8.721E-04

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap24 EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
8.851E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	5411	0.58	7.523E-02	8.94
1.000E-10	277148	29.94	6.300E-01	74.90
1.000E-11	904417	97.72	8.400E-01	99.86
5.334E-12	925566	100.00	8.411E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap0
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	4.525E-07	9.216E-08	3.901E-08	1.158E-08	6.705E-09	4.536E-09	2.351E-09	1.013E-09	5.250E-10	2.276E-10
		0	0	0	0	0	0	0	4184	675	3439
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.402E-02	2.846E-03	6.286E-03
NNE	22.5	3.199E-07	5.397E-08	1.518E-08	5.621E-09	3.144E-09	2.084E-09	1.055E-09	4.420E-10	2.260E-10	9.683E-11
		0	0	0	0	0	0	10095	7971	2614	11151
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.553E-02	2.829E-02	4.743E-03	8.670E-03
NE	45.0	2.628E-07	5.148E-08	1.585E-08	6.229E-09	3.579E-09	2.410E-09	1.241E-09	5.307E-10	2.741E-10	1.184E-10
		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	1.791E-02	1.954E-01	1.206E-01	1.310E-01	1.124E-01	4.161E-02	3.011E-02
ENE	67.5	2.305E-07	4.056E-08	1.172E-08	4.416E-09	2.493E-09	1.662E-09	8.476E-10	3.589E-10	1.849E-10	7.980E-11
		0	0	831	2696	4386	3344	33197	27817	45276	10856
		0.000E+00	0.000E+00	7.821E-02	9.561E-02	8.782E-02	4.464E-02	2.260E-01	8.018E-02	6.722E-02	6.944E-03
E	90.0	2.129E-07	4.206E-08	1.301E-08	5.122E-09	2.950E-09	1.991E-09	1.029E-09	4.426E-10	2.300E-10	9.992E-11
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	2.747E-02	1.991E-02	5.859E-02	8.812E-02	2.111E-01	1.320E-01	6.220E-02	1.282E-02
ESE	112.5	1.572E-07	2.820E-08	8.251E-09	3.141E-09	1.779E-09	1.187E-09	6.051E-10	2.553E-10	1.309E-10	5.605E-11
		0	0	1834	5115	5592	3585	38084	42248	88358	18498
		0.000E+00	0.000E+00	1.215E-01	1.290E-01	7.986E-02	3.417E-02	1.850E-01	8.663E-02	9.284E-02	8.326E-03
SE	135.0	1.074E-07	1.962E-08	5.795E-09	2.218E-09	1.256E-09	8.374E-10	4.261E-10	1.794E-10	9.185E-11	3.927E-11
		0	0	161	3310	6031	7377	21652	13437	17612	12881
		0.000E+00	0.000E+00	7.492E-03	5.896E-02	6.080E-02	4.960E-02	7.408E-02	1.936E-02	1.299E-02	4.062E-03
SSE	157.5	1.165E-07	1.871E-08	5.056E-09	1.815E-09	9.942E-10	6.490E-10	3.218E-10	1.310E-10	6.581E-11	2.758E-11
		0	0	38	1644	3882	5607	12087	33116	28901	8268
		0.000E+00	0.000E+00	1.543E-03	2.396E-02	3.099E-02	2.922E-02	3.124E-02	3.484E-02	1.527E-02	1.831E-03
S	180.0	1.804E-07	3.686E-08	1.158E-08	4.612E-09	2.656E-09	1.789E-09	9.204E-10	3.924E-10	2.019E-10	8.673E-11
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	3.926E-02	3.532E-02	6.995E-02	8.229E-02	1.315E-01	1.544E-02	6.171E-03

SSW	202.5	2.023E-07	3.518E-08	1.009E-08	3.792E-09	2.134E-09	1.419E-09	7.209E-10	3.033E-10	1.355E-10	6.669E-11
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.111E-02	2.868E-03	2.302E-03
SW	225.0	2.625E-07	4.952E-08	1.494E-08	5.804E-09	3.322E-09	2.234E-09	1.149E-09	4.912E-10	2.538E-10	1.097E-10
		0	0	0	0	0	0	20	0	4	1583
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.846E-04	0.000E+00	8.154E-06	1.394E-03
WSW	247.5	4.049E-07	7.189E-08	2.098E-08	7.971E-09	4.533E-09	3.040E-09	1.562E-09	6.674E-10	3.454E-10	1.496E-10
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.144E-05	5.211E-03	3.593E-03
W	270.0	5.207E-07	1.120E-07	3.629E-08	1.473E-08	8.622E-09	5.878E-09	3.074E-09	1.341E-09	7.005E-10	3.056E-10
		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.333E-01	0.000E+00	2.987E-01	1.050E-01	5.603E-03	4.354E-03
WNW	292.5	3.626E-07	5.933E-08	1.637E-08	5.978E-09	3.337E-09	2.214E-09	1.134E-09	4.735E-10	2.434E-10	1.048E-10
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.092E-02	1.576E-02	3.624E-03	7.393E-03
NW	315.0	3.344E-07	6.297E-08	1.903E-08	7.403E-09	4.246E-09	2.861E-09	1.476E-09	6.334E-10	3.279E-10	1.419E-10
		0	0	0	0	0	0	0	2246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.142E-02	0.000E+00	3.184E-03
NNW	337.5	4.316E-07	8.100E-08	2.446E-08	9.521E-09	5.467E-09	3.686E-09	1.904E-09	8.187E-10	4.247E-10	1.842E-10
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.389E-03	2.189E-03	4.529E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap0 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
5.207E-07	0	0.00	0.000E+00	0.00
1.000E-07	0	0.00	0.000E+00	0.00
1.000E-08	1094	0.12	1.057E-01	2.43
1.000E-09	147377	15.92	2.516E+00	57.89
1.000E-10	788288	85.17	4.266E+00	98.17
2.758E-11	925566	100.00	4.346E+00	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap6
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
@ POPULATION EXPOSURE (UG/YR)
@ POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :	0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR MID-ANGLE										
N 0.0	4.994E-08	1.017E-08	3.202E-09	1.278E-09	7.401E-10	5.007E-10	2.594E-10	1.118E-10	5.795E-11	2.512E-11
	0	0	0	0	0	0	0	4184	675	3439
	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.755E-03	3.141E-04	6.938E-04

NNE	22.5	3.531E-08	5.957E-09	1.675E-09	6.204E-10	3.470E-10	2.300E-10	1.165E-10	4.879E-11	2.494E-11	1.069E-11
		0	0	0	0	0	0	10095	7971	2614	11151
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.441E-03	3.123E-03	5.235E-04	9.570E-04
NE	45.0	2.900E-08	5.682E-09	1.749E-09	6.875E-10	3.950E-10	2.660E-10	1.370E-10	5.858E-11	3.025E-11	1.307E-11
		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	1.977E-03	2.156E-02	1.331E-02	1.446E-02	1.240E-02	4.593E-03	3.323E-03
ENE	67.5	2.544E-08	4.476E-09	1.294E-09	4.875E-10	2.752E-10	1.835E-10	9.355E-11	3.962E-11	2.041E-11	8.808E-12
		0	0	831	2696	4386	3344	33197	27817	45276	10836
		0.000E+00	0.000E+00	8.632E-03	1.055E-02	9.693E-03	4.927E-03	2.494E-02	8.849E-03	7.420E-03	7.664E-04
E	90.0	2.350E-08	4.642E-09	1.436E-09	5.653E-10	3.256E-10	2.197E-10	1.135E-10	4.886E-11	2.538E-11	1.103E-11
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	3.032E-03	2.197E-03	6.467E-03	9.726E-03	2.330E-02	1.457E-02	6.865E-03	1.414E-03
ESE	112.5	1.735E-08	3.112E-09	9.107E-10	3.467E-10	1.963E-10	1.310E-10	6.678E-11	2.818E-11	1.444E-11	6.186E-12
		0	0	1834	5115	5592	3585	38084	42248	88358	18498
		0.000E+00	0.000E+00	1.341E-02	1.424E-02	8.815E-03	3.771E-03	2.042E-02	9.561E-03	1.025E-02	9.189E-04
SE	135.0	1.185E-08	2.166E-09	6.396E-10	2.448E-10	1.386E-10	9.242E-11	4.703E-11	1.980E-11	1.014E-11	4.335E-12
		0	0	161	3310	6031	7377	21652	13437	17612	12881
		0.000E+00	0.000E+00	8.269E-04	6.507E-03	6.711E-03	5.475E-03	8.176E-03	2.137E-03	1.434E-03	4.484E-04
SSE	157.5	1.286E-08	2.065E-09	5.580E-10	2.003E-10	1.097E-10	7.163E-11	3.552E-11	1.446E-11	7.264E-12	3.044E-12
		0	0	38	1644	3882	5607	12087	33116	28901	8268
		0.000E+00	0.000E+00	1.703E-04	3.645E-03	3.420E-03	3.225E-03	3.448E-03	3.845E-03	1.686E-03	2.021E-04
S	180.0	1.991E-08	4.068E-09	1.278E-09	5.090E-10	2.932E-10	1.974E-10	1.016E-10	4.330E-11	2.229E-11	9.573E-12
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	4.333E-03	3.898E-03	7.721E-03	9.082E-03	1.451E-02	1.704E-03	6.812E-04
SSW	202.5	2.233E-08	3.883E-09	1.114E-09	4.185E-10	2.355E-10	1.566E-10	7.957E-11	3.348E-11	1.716E-11	7.361E-12
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.330E-03	3.165E-04	2.540E-04
SW	225.0	2.897E-08	5.466E-09	1.649E-09	6.406E-10	3.666E-10	2.465E-10	1.268E-10	5.422E-11	2.802E-11	1.210E-11
		0	0	0	0	0	0	20	0	4	1583
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.037E-05	0.000E+00	8.999E-07	1.538E-04
WSW	247.5	4.469E-08	7.934E-09	2.315E-09	8.798E-10	5.003E-10	3.356E-10	1.724E-10	7.367E-11	3.812E-11	1.651E-11
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.366E-06	5.751E-04	3.965E-04
W	270.0	5.748E-08	1.236E-08	4.006E-09	1.626E-09	9.516E-10	6.487E-10	3.392E-10	1.480E-10	7.732E-11	3.373E-11
		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.472E-02	0.000E+00	3.297E-02	1.159E-02	6.184E-04	4.805E-04
WNW	292.5	4.002E-08	6.549E-09	1.807E-09	6.598E-10	3.684E-10	2.444E-10	1.240E-10	5.226E-11	2.687E-11	1.156E-11
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.309E-03	1.739E-03	4.000E-04	8.160E-04
NW	315.0	3.690E-08	6.950E-09	2.100E-09	8.170E-10	4.687E-10	3.157E-10	1.629E-10	6.991E-11	3.619E-11	1.566E-11
		0	0	0	0	0	0	0	2246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.261E-03	0.000E+00	3.514E-04
NNW	337.5	4.763E-08	8.940E-09	2.700E-09	1.051E-09	6.034E-10	4.068E-10	2.101E-10	9.036E-11	4.688E-11	2.033E-11
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.422E-04	2.417E-04	4.998E-04

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap6 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
5.748E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	1094	0.12	1.166E-02	2.43
1.000E-10	162393	17.55	2.902E-01	60.50
1.000E-11	833023	90.00	4.747E-01	98.97
3.044E-12	925566	100.00	4.797E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap12
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
♦ POPULATION EXPOSURE (UG/YR)
♦ POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION x POPULATION x ANNUAL BREATHING RATE(22.0M3/DAY x 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	4.773E-08	9.721E-09	3.060E-09	1.222E-09	7.073E-10	4.785E-10	2.479E-10	1.068E-10	5.538E-11	2.401E-11
		0	0	0	0	0	0	0	4184	675	3439
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.588E-03	3.002E-04	6.630E-04
NNE	22.5	3.375E-08	5.692E-09	1.601E-09	5.929E-10	3.316E-10	2.198E-10	1.113E-10	4.662E-11	2.384E-11	1.021E-11
		0	0	0	0	0	0	10095	7971	2614	11151
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.022E-03	2.984E-03	5.003E-04	9.145E-04
NE	45.0	2.772E-08	5.430E-09	1.672E-09	6.571E-10	3.775E-10	2.542E-10	1.309E-10	5.598E-11	2.891E-11	1.249E-11
		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	1.889E-03	2.061E-02	1.272E-02	1.382E-02	1.186E-02	4.389E-03	3.176E-03
ENE	67.5	2.431E-08	4.278E-09	1.236E-09	4.658E-10	2.630E-10	1.754E-10	8.941E-11	3.786E-11	1.950E-11	8.418E-12
		0	0	831	2696	4386	3344	33197	27817	45276	10836
		0.000E+00	0.000E+00	8.249E-03	1.008E-02	9.263E-03	4.709E-03	2.383E-02	8.457E-03	7.091E-03	7.324E-04
E	90.0	2.246E-08	4.437E-09	1.372E-09	5.403E-10	3.112E-10	2.100E-10	1.085E-10	4.669E-11	2.426E-11	1.054E-11
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	2.897E-03	2.100E-03	6.180E-03	9.295E-03	2.227E-02	1.392E-02	6.561E-03	1.352E-03
ESE	112.5	1.658E-08	2.974E-09	8.703E-10	3.313E-10	1.876E-10	1.252E-10	6.382E-11	2.693E-11	1.380E-11	5.912E-12
		0	0	1834	5115	5592	3585	38084	42248	88358	18498
		0.000E+00	0.000E+00	1.282E-02	1.361E-02	8.424E-03	3.604E-03	1.952E-02	9.137E-03	9.793E-03	8.782E-04
SE	135.0	1.133E-08	2.070E-09	6.112E-10	2.340E-10	1.324E-10	8.832E-11	4.494E-11	1.892E-11	9.688E-12	4.143E-12
		0	0	161	3310	6031	7377	21652	13437	17612	12881
		0.000E+00	0.000E+00	7.902E-04	6.219E-03	6.413E-03	5.232E-03	7.814E-03	2.042E-03	1.370E-03	4.285E-04
SSE	157.5	1.229E-08	1.973E-09	5.333E-10	1.915E-10	1.049E-10	6.845E-11	3.395E-11	1.382E-11	6.942E-12	2.909E-12
		0	0	38	1644	3882	5607	12087	33116	28901	8268

		0.000E+00	0.000E+00	1.627E-04	2.528E-03	3.269E-03	3.082E-03	3.295E-03	3.675E-03	1.611E-03	1.932E-04
S	180.0	1.903E-08	3.888E-09	1.222E-09	4.865E-10	2.802E-10	1.887E-10	9.708E-11	4.139E-11	2.130E-11	9.149E-12
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	4.141E-03	3.726E-03	7.378E-03	8.680E-03	1.387E-02	1.629E-03	6.510E-04
SSW	202.5	2.134E-08	3.711E-09	1.065E-09	3.999E-10	2.250E-10	1.497E-10	7.604E-11	3.200E-11	1.640E-11	7.034E-12
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.237E-03	3.925E-04	2.428E-04
SW	225.0	2.769E-08	5.224E-09	1.576E-09	6.122E-10	3.504E-10	2.356E-10	1.212E-10	5.182E-11	2.678E-11	1.157E-11
		0	0	0	0	0	0	20	0	4	1583
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.947E-05	0.000E+00	8.600E-07	1.470E-04
WSW	247.5	4.271E-08	7.583E-09	2.213E-09	8.408E-10	4.782E-10	3.207E-10	1.647E-10	7.040E-11	3.643E-11	1.578E-11
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.261E-06	5.496E-04	3.789E-04
W	270.0	5.493E-08	1.181E-08	3.828E-09	1.554E-09	9.094E-10	6.200E-10	3.242E-10	1.414E-10	7.389E-11	3.224E-11
		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.406E-02	0.000E+00	3.151E-02	1.107E-02	5.910E-04	4.592E-04
WNW	292.5	3.825E-08	6.258E-09	1.727E-09	6.306E-10	3.520E-10	2.336E-10	1.185E-10	4.995E-11	2.568E-11	1.105E-11
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.206E-03	1.662E-03	3.823E-04	7.798E-04
NW	315.0	3.527E-08	6.642E-09	2.007E-09	7.808E-10	4.479E-10	3.017E-10	1.557E-10	6.681E-11	3.459E-11	1.497E-11
		0	0	0	0	0	0	0	2246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.205E-03	0.000E+00	3.358E-04
NNW	337.5	4.552E-08	8.543E-09	2.580E-09	1.004E-09	5.766E-10	3.888E-10	2.008E-10	8.636E-11	4.480E-11	1.943E-11
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.359E-04	2.309E-04	4.777E-04

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap12 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
5.493E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	1094	0.12	1.115E-02	2.43
1.000E-10	151259	16.34	2.687E-01	58.61
1.000E-11	815411	88.10	4.523E-01	98.67
2.909E-12	925566	100.00	4.584E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; MEMPHIS SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap24
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
@ POPULATION EXPOSURE (UG/YR)
@ POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION A POPULATION A ANNUAL BREATHING RATE(22.0M3/DAY A 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	4.356E-08	8.874E-09	2.794E-09	1.115E-09	6.456E-10	4.368E-10	2.263E-10	9.749E-11	5.055E-11	2.192E-11
		0	0	0	0	0	0	0	4184	675	3439
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.276E-03	2.740E-04	6.052E-04
NNE	22.5	3.081E-08	5.196E-09	1.461E-09	5.412E-10	3.027E-10	2.006E-10	1.016E-10	4.256E-11	2.176E-11	9.323E-12
		0	0	0	0	0	0	10095	7971	2614	11151
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.235E-03	2.724E-03	4.567E-04	8.348E-04
NE	45.0	2.530E-08	4.957E-09	1.526E-09	5.998E-10	3.446E-10	2.321E-10	1.195E-10	5.110E-11	2.639E-11	1.140E-11
		0	0	0	358	6798	6230	13148	26373	18908	31666
		0.000E+00	0.000E+00	0.000E+00	1.724E-03	1.881E-02	1.161E-02	1.262E-02	1.082E-02	4.007E-03	2.899E-03
ENE	67.5	2.219E-08	3.905E-09	1.128E-09	4.252E-10	2.401E-10	1.601E-10	8.161E-11	3.456E-11	1.780E-11	7.684E-12
		0	0	831	2696	4386	3344	33197	27817	45276	10836
		0.000E+00	0.000E+00	7.530E-03	9.206E-03	8.455E-03	4.298E-03	2.176E-02	7.720E-03	6.472E-03	6.686E-04
E	90.0	2.050E-08	4.050E-09	1.252E-09	4.931E-10	2.841E-10	1.917E-10	9.904E-11	4.262E-11	2.214E-11	9.621E-12
		0	0	263	484	2473	5512	25561	37137	33683	15972
		0.000E+00	0.000E+00	2.645E-03	1.917E-03	5.641E-03	8.485E-03	2.033E-02	1.371E-02	5.989E-03	1.234E-03
ESE	112.5	1.514E-08	2.715E-09	7.944E-10	3.024E-10	1.712E-10	1.143E-10	5.826E-11	2.459E-11	1.260E-11	5.397E-12
		0	0	1834	5115	5592	3585	38084	42248	88358	18498
		0.000E+00	0.000E+00	1.170E-02	1.242E-02	7.689E-03	3.290E-03	1.782E-02	8.341E-03	8.939E-03	8.016E-04
SE	135.0	1.034E-08	1.889E-09	5.579E-10	2.136E-10	1.209E-10	8.062E-11	4.102E-11	1.727E-11	8.843E-12	3.781E-12
		0	0	161	3310	6031	7377	21652	13437	17612	12881
		0.000E+00	0.000E+00	7.213E-04	5.676E-03	5.854E-03	4.776E-03	7.132E-03	1.864E-03	1.251E-03	3.911E-04
SSE	157.5	1.122E-08	1.801E-09	4.868E-10	1.748E-10	9.572E-11	6.248E-11	3.099E-11	1.261E-11	6.336E-12	2.656E-12
		0	0	38	1644	3882	5607	12087	33116	28901	8268
		0.000E+00	0.000E+00	1.485E-04	2.307E-03	2.984E-03	2.813E-03	3.008E-03	3.355E-03	1.471E-03	1.763E-04
S	180.0	1.737E-08	3.549E-09	1.115E-09	4.441E-10	2.557E-10	1.722E-10	8.862E-11	3.778E-11	1.944E-11	8.351E-12
		0	0	0	1060	1656	4870	11134	41731	9522	8861
		0.000E+00	0.000E+00	0.000E+00	3.780E-03	3.401E-03	6.735E-03	7.923E-03	1.266E-02	1.487E-03	5.942E-04
SSW	202.5	1.948E-08	3.387E-09	9.718E-10	3.651E-10	2.054E-10	1.366E-10	6.941E-11	2.921E-11	1.497E-11	6.421E-12
		0	0	0	0	0	0	0	8666	2297	4298
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.032E-03	2.761E-04	2.216E-04
SW	225.0	2.528E-08	4.768E-09	1.439E-09	5.588E-10	3.198E-10	2.151E-10	1.106E-10	4.730E-11	2.444E-11	1.056E-11
		0	0	0	0	0	0	20	0	4	1583
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.777E-05	0.000E+00	7.850E-07	1.342E-04
WSW	247.5	3.898E-08	6.921E-09	2.020E-09	7.675E-10	4.365E-10	2.927E-10	1.504E-10	6.426E-11	3.325E-11	1.440E-11
		0	0	0	0	0	0	0	4	1879	2991
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.064E-06	5.017E-04	3.459E-04
W	270.0	5.014E-08	1.078E-08	3.495E-09	1.418E-09	8.301E-10	5.659E-10	2.959E-10	1.291E-10	6.745E-11	2.943E-11
		0	0	0	0	1926	0	12104	9750	996	1774
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.284E-02	0.000E+00	2.876E-02	1.011E-02	5.394E-04	4.192E-04
WNW	292.5	3.491E-08	5.713E-09	1.576E-09	5.756E-10	3.213E-10	2.132E-10	1.082E-10	4.559E-11	2.344E-11	1.009E-11
		0	0	0	0	0	0	2318	4144	1854	8789
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.014E-03	1.517E-03	3.489E-04	7.118E-04
NW	315.0	3.219E-08	6.063E-09	1.832E-09	7.127E-10	4.088E-10	2.754E-10	1.421E-10	6.099E-11	3.157E-11	1.366E-11

		0	0	0	0	0	0	0	2246	0	2794
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.100E-03	0.000E+00	3.065E-04
NNW	337.5	4.155E-08	7.799E-09	2.355E-09	9.167E-10	5.264E-10	3.549E-10	1.833E-10	7.883E-11	4.089E-11	1.774E-11
		0	0	0	0	0	0	0	196	642	3061
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.241E-04	2.108E-04	4.360E-04

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap24 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND MEMPHIS

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
5.014E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	1094	0.12	1.017E-02	2.43
1.000E-10	117632	12.71	2.186E-01	52.25
1.000E-11	788288	85.17	4.108E-01	98.17
2.656E-12	925566	100.00	4.184E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

TACOMA SCENARIO
POLLUTANT ; nCb
SITE ; TACOMA SOURCE CATEGORY ; one acre EMISSION TYPE ; capO
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION x POPULATION x ANNUAL BREATHING RATE(22.0M3/DAY x 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	7.224E-08	1.374E-08	4.076E-09	1.550E-09	8.692E-10	5.751E-10	2.889E-10	1.190E-10	5.968E-11	2.471E-11
		0	0	0	1915	0	4330	765	0	22057	417243
		0.000E+00	0.000E+00	0.000E+00	2.383E-02	0.000E+00	2.000E-02	1.775E-03	0.000E+00	1.057E-02	8.280E-02
NNE	22.5	8.089E-08	1.684E-08	5.222E-09	2.046E-09	1.159E-09	7.704E-10	3.882E-10	1.599E-10	8.005E-11	3.397E-11
		0	0	0	0	553	4974	14804	12041	58778	287872
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.147E-03	3.077E-02	4.615E-02	1.546E-02	3.778E-02	7.622E-02
NE	45.0	7.153E-08	1.447E-08	4.401E-09	1.701E-09	9.581E-10	6.346E-10	3.188E-10	1.310E-10	6.559E-11	2.708E-11
		0	0	0	0	0	2135	13657	14840	45395	68241
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.088E-02	3.496E-02	1.562E-02	2.391E-02	1.484E-02
ENE	67.5	4.786E-08	9.069E-09	2.670E-09	1.006E-09	5.599E-10	3.683E-10	1.837E-10	7.508E-11	3.758E-11	1.561E-11
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	2.680E-02	0.000E+00	0.000E+00	0.000E+00	6.119E-03	1.119E-02	7.278E-03	1.896E-03
E	90.0	3.103E-08	5.426E-09	1.519E-09	5.504E-10	3.019E-10	1.971E-10	9.765E-11	3.986E-11	2.009E-11	8.462E-12
		0	0	0	0	663	456	2911	12676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.607E-03	7.215E-04	2.283E-03	4.057E-03	1.722E-03	5.265E-04
ESE	112.5	2.756E-08	5.273E-09	1.569E-09	5.912E-10	3.298E-10	2.172E-10	1.087E-10	4.494E-11	2.283E-11	9.735E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.865E-03	0.000E+00	8.477E-03	2.145E-03	1.223E-03	1.132E-03
SE	135.0	3.230E-08	5.719E-09	1.614E-09	5.878E-10	3.244E-10	2.129E-10	1.063E-10	4.395E-11	2.235E-11	9.546E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.327E-03	5.662E-03	3.714E-03	2.024E-04
SSE	157.5	5.016E-08	9.714E-09	2.912E-09	1.112E-09	6.287E-10	4.191E-10	2.132E-10	8.992E-11	4.610E-11	1.976E-11
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	3.668E-03	0.000E+00	5.169E-03	2.728E-03	9.318E-03	4.998E-03	1.007E-03
S	180.0	7.393E-08	1.515E-08	4.669E-09	1.818E-09	1.037E-09	6.945E-10	3.551E-10	1.504E-10	7.715E-11	3.301E-11
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.503E-03	3.362E-02	1.176E-02	1.362E-02	2.732E-03
SSW	202.5	8.629E-08	1.792E-08	5.553E-09	2.174E-09	1.245E-09	8.357E-10	4.288E-10	1.824E-10	9.372E-11	4.019E-11
		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.188E-03	1.905E-02	1.029E-01	3.948E-02	1.167E-02	2.801E-03
SW	225.0	7.662E-08	1.610E-08	5.083E-09	2.015E-09	1.162E-09	7.839E-10	4.046E-10	1.735E-10	8.959E-11	3.857E-11
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	6.041E-03	0.000E+00	0.000E+00	4.406E-03	6.401E-02	3.491E-02	4.170E-02	1.897E-02
WSW	247.5	6.045E-08	1.059E-08	2.967E-09	1.077E-09	5.968E-10	3.935E-10	1.980E-10	8.242E-11	4.201E-11	1.789E-11
		0	0	0	0	1008	5794	25835	25625	642	26351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.831E-03	1.831E-02	4.107E-02	1.696E-02	2.166E-04	3.786E-03
W	270.0	7.004E-08	1.428E-08	4.464E-09	1.758E-09	1.010E-09	6.796E-10	3.493E-10	1.488E-10	7.644E-11	3.261E-11

		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.718E-03	8.470E-02	1.649E-02	8.900E-04	1.823E-03
WNW	292.5	8.752E-08	1.761E-08	5.353E-09	2.069E-09	1.176E-09	7.857E-10	4.004E-10	1.685E-10	8.588E-11	3.634E-11
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	1.126E-02	0.000E+00	0.000E+00	0.000E+00	1.337E-02	2.533E-03	6.816E-03	2.250E-03
NW	315.0	9.136E-08	1.949E-08	6.174E-09	2.454E-09	1.410E-09	9.475E-10	4.854E-10	2.053E-10	1.046E-10	4.419E-11
		0	0	0	0	0	0	1168	769	7919	19737
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.552E-03	1.267E-03	6.654E-03	7.004E-03
NNW	337.5	7.565E-08	1.427E-08	4.197E-09	1.585E-09	8.879E-10	5.874E-10	2.954E-10	1.219E-10	6.135E-11	2.552E-11
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.104E-03	1.836E-03	1.272E-03	2.238E-03	2.008E-02

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap0 EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
9.136E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	4958	0.28	8.094E-02	6.36
1.000E-10	319902	17.90	8.139E-01	63.99
1.000E-11	1762216	98.61	1.270E+00	99.85
8.462E-12	1787083	100.00	1.272E+00	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; TACOMA SOURCE CATEGORY ; one acre EMISSION TYPE ; cap6
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	2.581E-08	4.909E-09	1.457E-09	5.538E-10	3.106E-10	2.055E-10	1.032E-10	4.251E-11	2.133E-11	8.832E-12
		0	0	0	1915	0	4330	765	0	22057	417243
		0.000E+00	0.000E+00	0.000E+00	8.517E-03	0.000E+00	7.146E-03	6.342E-04	0.000E+00	3.778E-03	2.959E-02
NNE	22.5	2.891E-08	6.017E-09	1.866E-09	7.311E-10	4.142E-10	2.753E-10	1.387E-10	5.716E-11	2.861E-11	1.178E-11
		0	0	0	0	553	4974	14804	12041	58778	287872
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.839E-03	1.100E-02	1.649E-02	5.526E-03	1.350E-02	2.724E-02
NE	45.0	2.556E-08	5.171E-09	1.573E-09	6.077E-10	3.424E-10	2.268E-10	1.139E-10	4.683E-11	2.344E-11	9.678E-12
		0	0	0	0	0	2135	13657	14840	45395	68241
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.888E-03	1.249E-02	5.580E-03	8.545E-03	5.303E-03
ENE	67.5	1.710E-08	3.241E-09	9.542E-10	3.594E-10	2.001E-10	1.316E-10	6.564E-11	2.683E-11	1.343E-11	5.578E-12
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	9.578E-03	0.000E+00	0.000E+00	0.000E+00	2.187E-03	4.000E-03	2.601E-03	6.774E-04

E	90.0	1.109E-08	1.939E-09	5.428E-10	1.967E-10	1.079E-10	7.042E-11	3.490E-11	1.424E-11	7.178E-12	3.024E-12
		0	0	0	0	663	456	2911	12676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.744E-04	2.578E-04	8.157E-04	1.450E-03	6.152E-04	1.882E-04
ESE	112.5	9.849E-09	1.884E-09	5.606E-10	2.113E-10	1.179E-10	7.762E-11	3.884E-11	1.606E-11	8.157E-12	3.479E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.739E-03	0.000E+00	3.029E-03	7.667E-04	4.372E-04	4.044E-04
SE	135.0	1.154E-08	2.044E-09	5.769E-10	2.101E-10	1.159E-10	7.607E-11	3.800E-11	1.571E-11	7.988E-12	3.411E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.317E-04	2.023E-03	1.327E-03	7.235E-05
SSE	157.5	1.792E-08	3.471E-09	1.041E-09	3.972E-10	2.247E-10	1.498E-10	7.620E-11	3.213E-11	1.647E-11	7.060E-12
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	1.311E-03	0.000E+00	1.847E-03	9.748E-04	3.330E-03	1.786E-03	3.598E-04
S	180.0	2.642E-08	5.413E-09	1.668E-09	6.496E-10	3.706E-10	2.482E-10	1.269E-10	5.375E-11	2.757E-11	1.180E-11
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.324E-03	1.201E-02	4.201E-03	4.867E-03	9.761E-04
SSW	202.5	3.083E-08	6.405E-09	1.984E-09	7.770E-10	4.448E-10	2.986E-10	1.532E-10	6.517E-11	3.349E-11	1.436E-11
		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.497E-03	6.808E-03	3.676E-02	1.411E-02	4.171E-03	1.001E-03
SW	225.0	2.738E-08	5.753E-09	1.817E-09	7.202E-10	4.152E-10	2.801E-10	1.446E-10	6.199E-11	3.202E-11	1.378E-11
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	2.159E-03	0.000E+00	0.000E+00	1.575E-03	2.287E-02	1.248E-02	1.490E-02	6.779E-03
WSW	247.5	2.160E-08	3.783E-09	1.060E-09	3.850E-10	2.133E-10	1.406E-10	7.074E-11	2.945E-11	1.501E-11	6.394E-12
		0	0	0	0	1008	5794	25835	25625	642	26351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.726E-03	6.542E-03	1.468E-02	6.060E-03	7.740E-05	1.353E-03
W	270.0	2.503E-08	5.104E-09	1.595E-09	6.282E-10	3.609E-10	2.429E-10	1.248E-10	5.317E-11	2.732E-11	1.165E-11
		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.401E-03	3.027E-02	5.893E-03	3.180E-04	6.513E-04
WNW	292.5	3.128E-08	6.292E-09	1.913E-09	7.392E-10	4.201E-10	2.808E-10	1.431E-10	6.021E-11	3.069E-11	1.299E-11
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	4.025E-03	0.000E+00	0.000E+00	0.000E+00	4.776E-03	9.050E-04	2.436E-03	8.040E-04
NW	315.0	3.265E-08	6.964E-09	2.206E-09	8.769E-10	5.037E-10	3.386E-10	1.735E-10	7.335E-11	3.739E-11	1.579E-11
		0	0	0	0	0	0	1168	769	7919	19737
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.627E-03	4.529E-04	2.378E-03	2.503E-03
NNW	337.5	2.703E-08	5.099E-09	1.500E-09	5.665E-10	3.173E-10	2.099E-10	1.056E-10	4.358E-11	2.192E-11	9.120E-12
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.824E-03	6.561E-04	4.545E-04	7.996E-04	7.175E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM capG EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
3.265E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	410	0.02	6.184E-03	1.36

1.000E-10	161135	9.02	2.169E-01	47.72
1.000E-11	1092899	61.16	4.070E-01	89.55
3.024E-12	1787083	100.00	4.545E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; TACOMA SOURCE CATEGORY ; one acre EMISSION TYPE ; cap12
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	2.462E-08	4.682E-09	1.389E-09	5.283E-10	2.963E-10	1.960E-10	9.847E-11	4.055E-11	2.034E-11	8.424E-12
		0	0	0	1915	0	4330	765	0	22057	417243
		0.000E+00	0.000E+00	0.000E+00	8.123E-03	0.000E+00	6.815E-03	6.049E-04	0.000E+00	3.603E-03	2.822E-02
NNE	22.5	2.757E-08	5.739E-09	1.780E-09	6.973E-10	3.951E-10	2.626E-10	1.323E-10	5.451E-11	2.728E-11	1.124E-11
		0	0	0	0	553	4974	14804	12041	58778	287872
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.754E-03	1.049E-02	1.573E-02	5.271E-03	1.288E-02	2.598E-02
NE	45.0	2.438E-08	4.932E-09	1.500E-09	5.796E-10	3.265E-10	2.163E-10	1.086E-10	4.466E-11	2.236E-11	9.231E-12
		0	0	0	0	0	2135	13657	14840	45395	68241
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.708E-03	1.192E-02	5.322E-03	8.150E-03	5.058E-03
ENE	67.5	1.631E-08	3.091E-09	9.101E-10	3.427E-10	1.908E-10	1.255E-10	6.260E-11	2.559E-11	1.281E-11	5.320E-12
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	9.135E-03	0.000E+00	0.000E+00	0.000E+00	2.086E-03	3.815E-03	2.481E-03	6.461E-04
E	90.0	1.058E-08	1.850E-09	5.177E-10	1.876E-10	1.029E-10	6.716E-11	3.328E-11	1.359E-11	6.846E-12	2.884E-12
		0	0	0	0	663	456	2911	12676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.478E-04	2.459E-04	7.780E-04	1.383E-03	5.868E-04	1.795E-04
ESE	112.5	9.394E-09	1.797E-09	5.347E-10	2.015E-10	1.124E-10	7.404E-11	3.704E-11	1.532E-11	7.780E-12	3.318E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.658E-03	0.000E+00	2.889E-03	7.313E-04	4.169E-04	3.857E-04
SE	135.0	1.101E-08	1.949E-09	5.502E-10	2.004E-10	1.106E-10	7.256E-11	3.624E-11	1.498E-11	7.619E-12	3.254E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.933E-04	1.930E-03	1.266E-03	6.900E-05
SSE	157.5	1.710E-08	3.311E-09	9.925E-10	3.788E-10	2.143E-10	1.428E-10	7.268E-11	3.065E-11	1.571E-11	6.734E-12
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	1.250E-03	0.000E+00	1.762E-03	9.297E-04	3.176E-03	1.703E-03	3.431E-04
S	180.0	2.520E-08	5.163E-09	1.591E-09	6.196E-10	3.535E-10	2.367E-10	1.210E-10	5.127E-11	2.630E-11	1.125E-11
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.216E-03	1.146E-02	4.007E-03	4.642E-03	9.310E-04
SSW	202.5	2.941E-08	6.109E-09	1.893E-09	7.411E-10	4.242E-10	2.848E-10	1.462E-10	6.216E-11	3.194E-11	1.370E-11
		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.427E-03	6.494E-03	3.507E-02	1.346E-02	3.978E-03	9.548E-04
SW	225.0	2.612E-08	5.487E-09	1.733E-09	6.869E-10	3.960E-10	2.672E-10	1.379E-10	5.913E-11	3.054E-11	1.315E-11
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	2.059E-03	0.000E+00	0.000E+00	1.502E-03	2.182E-02	1.190E-02	1.421E-02	6.465E-03

WSW	247.5	2.061E-08	3.608E-09	1.011E-09	3.672E-10	2.034E-10	1.341E-10	6.747E-11	2.809E-11	1.432E-11	6.098E-12
		0	0	0	0	1008	5794	25835	25625	642	26351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.647E-03	6.240E-03	1.400E-02	5.780E-03	7.382E-05	1.290E-03
W	270.0	2.387E-08	4.868E-09	1.522E-09	5.992E-10	3.442E-10	2.316E-10	1.191E-10	5.072E-11	2.605E-11	1.111E-11
		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.290E-03	2.887E-02	5.621E-03	3.033E-04	6.212E-04
WNW	292.5	2.983E-08	6.001E-09	1.825E-09	7.051E-10	4.007E-10	2.678E-10	1.365E-10	5.742E-11	2.927E-11	1.239E-11
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	3.839E-03	0.000E+00	0.000E+00	0.000E+00	4.556E-03	8.632E-04	2.323E-03	7.669E-04
NW	315.0	3.114E-08	6.642E-09	2.104E-09	8.364E-10	4.804E-10	3.229E-10	1.654E-10	6.996E-11	3.567E-11	1.506E-11
		0	0	0	0	0	0	1168	769	7919	19737
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.552E-03	4.320E-04	2.268E-03	2.387E-03
NNW	337.5	2.578E-08	4.863E-09	1.431E-09	5.403E-10	3.026E-10	2.002E-10	1.007E-10	4.156E-11	2.091E-11	8.699E-12
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.740E-03	6.258E-04	4.335E-04	7.626E-04	6.843E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap12 EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
3.114E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	410	0.02	5.898E-03	1.36
1.000E-10	160370	8.97	2.063E-01	47.58
1.000E-11	1092899	61.16	3.882E-01	89.55
2.884E-12	1787083	100.00	4.335E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; TACOMA SOURCE CATEGORY ; one acre EMISSION TYPE ; cap24
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
@ POPULATION EXPOSURE (UG/YR)
@ POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :	0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR MID-ANGLE										
N 0.0	2.245E-08	4.270E-09	1.367E-09	4.817E-10	2.702E-10	1.787E-10	8.980E-11	3.697E-11	1.855E-11	7.681E-12
	0	0	0	1915	0	4330	765	0	22057	417243
	0.000E+00	0.000E+00	0.000E+00	7.407E-03	0.000E+00	6.215E-03	5.516E-04	0.000E+00	3.286E-03	2.574E-02
NNE 22.5	2.514E-08	5.233E-09	1.623E-09	6.358E-10	3.603E-10	2.394E-10	1.207E-10	4.971E-11	2.488E-11	1.025E-11
	0	0	0	0	553	4974	14804	12041	58778	387872
	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.600E-03	9.564E-03	1.434E-02	4.806E-03	1.174E-02	2.369E-02
NE 45.0	2.223E-08	4.497E-09	1.368E-09	5.286E-10	2.978E-10	1.973E-10	9.908E-11	4.073E-11	2.039E-11	8.418E-12
	0	0	0	0	0	2135	13657	14840	45395	68241

		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.382E-03	1.087E-02	4.853E-03	7.432E-03	4.613E-03
ENE	67.5	1.488E-08	2.819E-09	8.299E-10	3.125E-10	1.740E-10	1.145E-10	5.709E-11	2.333E-11	1.168E-11	4.851E-12
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	8.330E-03	0.000E+00	0.000E+00	0.000E+00	1.902E-03	3.479E-03	2.262E-03	5.892E-04
E	90.0	9.645E-09	1.687E-09	4.721E-10	1.711E-10	9.384E-11	6.125E-11	3.035E-11	1.239E-11	6.243E-12	2.630E-12
		0	0	0	0	663	456	2911	12676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.996E-04	2.243E-04	7.094E-04	1.261E-03	5.351E-04	1.636E-04
ESE	112.5	8.566E-09	1.639E-09	4.876E-10	1.837E-10	1.025E-10	6.751E-11	3.378E-11	1.397E-11	7.095E-12	3.026E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.512E-03	0.000E+00	2.635E-03	6.668E-04	3.802E-04	3.518E-04
SE	135.0	1.004E-08	1.777E-09	5.017E-10	1.827E-10	1.008E-10	6.616E-11	3.305E-11	1.366E-11	6.947E-12	2.967E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.234E-04	1.760E-03	1.154E-03	6.292E-05
SSE	157.5	1.559E-08	3.019E-09	9.051E-10	3.455E-10	1.954E-10	1.303E-10	6.628E-11	2.795E-11	1.433E-11	6.140E-12
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	1.140E-03	0.000E+00	1.607E-03	8.478E-04	2.896E-03	1.553E-03	3.129E-04
S	180.0	2.298E-08	4.708E-09	1.451E-09	5.650E-10	3.223E-10	2.159E-10	1.104E-10	4.675E-11	2.398E-11	1.026E-11
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.021E-03	1.045E-02	3.654E-03	4.233E-03	8.490E-04
SSW	202.5	2.682E-08	5.571E-09	1.726E-09	6.758E-10	3.868E-10	2.597E-10	1.333E-10	5.668E-11	2.913E-11	1.249E-11
		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.302E-03	5.921E-03	3.198E-02	1.227E-02	3.628E-03	8.706E-04
SW	225.0	2.381E-08	5.003E-09	1.580E-09	6.264E-10	3.611E-10	2.437E-10	1.258E-10	5.392E-11	2.785E-11	1.199E-11
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	1.878E-03	0.000E+00	0.000E+00	1.370E-03	1.989E-02	1.085E-02	1.296E-02	5.896E-03
WSW	247.5	1.879E-08	3.290E-09	9.221E-10	3.349E-10	1.855E-10	1.223E-10	6.153E-11	2.562E-11	1.306E-11	5.561E-12
		0	0	0	0	1008	5794	25835	25625	642	26351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.502E-03	5.690E-03	1.276E-02	5.271E-03	6.732E-05	1.177E-03
W	270.0	2.177E-08	4.439E-09	1.388E-09	5.464E-10	3.139E-10	2.112E-10	1.086E-10	4.625E-11	2.376E-11	1.013E-11
		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.088E-03	2.632E-02	5.126E-03	2.766E-04	5.665E-04
WNW	292.5	2.720E-08	5.472E-09	1.664E-09	6.429E-10	3.654E-10	2.442E-10	1.244E-10	5.236E-11	2.669E-11	1.130E-11
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	3.501E-03	0.000E+00	0.000E+00	0.000E+00	4.154E-03	7.871E-04	2.118E-03	6.993E-04
NW	315.0	2.840E-08	6.057E-09	1.919E-09	7.627E-10	4.381E-10	2.945E-10	1.509E-10	6.380E-11	3.252E-11	1.374E-11
		0	0	0	0	0	0	1168	769	7919	19737
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.415E-03	3.940E-04	2.068E-03	2.177E-03
NNW	337.5	2.351E-08	4.435E-09	1.305E-09	4.927E-10	2.760E-10	1.826E-10	9.181E-11	3.790E-11	1.907E-11	7.932E-12
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.586E-03	5.706E-04	3.953E-04	6.954E-04	6.240E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap24 EMISSIONS UNDER ISC SOURCE CATEGORY one acre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
2.840E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	410	0.02	5.378E-03	1.36
1.000E-10	145276	8.13	1.762E-01	44.56
1.000E-11	1092899	61.16	3.540E-01	89.55
2.630E-12	1787083	100.00	3.953E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; TACOMA SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap0
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	3.834E-08	6.855E-09	2.002E-09	7.631E-10	4.292E-10	2.846E-10	1.434E-10	5.925E-11	2.978E-11	1.235E-11
		0	0	0	1915	0	4330	765	0	22057	417243
		0.000E+00	0.000E+00	0.000E+00	1.173E-02	0.000E+00	9.897E-03	8.810E-04	0.000E+00	5.275E-03	4.137E-02
NNE	22.5	4.476E-08	8.618E-09	2.618E-09	1.022E-09	5.785E-10	3.846E-10	1.939E-10	7.995E-11	4.003E-11	1.650E-11
		0	0	0	0	553	4974	14804	12041	58778	287872
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.569E-03	1.536E-02	2.305E-02	7.731E-03	1.890E-02	3.813E-02
NE	45.0	3.936E-08	7.343E-09	2.192E-09	8.455E-10	4.766E-10	3.160E-10	1.589E-10	6.542E-11	3.278E-11	1.355E-11
		0	0	0	0	0	2135	13657	14840	45395	68241
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.418E-03	1.743E-02	7.796E-03	1.195E-02	7.422E-03
ENE	67.5	2.552E-08	4.548E-09	1.317E-09	4.963E-10	2.769E-10	1.825E-10	9.125E-11	3.741E-11	1.876E-11	7.800E-12
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	1.322E-02	0.000E+00	0.000E+00	0.000E+00	3.040E-03	5.577E-03	3.632E-03	9.474E-04
E	90.0	1.612E-08	2.669E-09	7.365E-10	2.683E-10	1.479E-10	9.690E-11	4.824E-11	1.980E-11	1.000E-11	4.224E-12
		0	0	0	0	663	456	2911	13676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.874E-04	3.548E-04	1.128E-03	2.015E-03	8.575E-04	2.628E-04
ESE	112.5	1.468E-08	2.685E-09	7.827E-10	2.941E-10	1.641E-10	1.081E-10	5.418E-11	2.244E-11	1.141E-11	4.868E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.421E-03	0.000E+00	4.226E-03	1.071E-03	6.113E-04	5.660E-04
SE	135.0	1.680E-08	2.814E-09	7.828E-10	2.865E-10	1.589E-10	1.047E-10	5.251E-11	2.182E-11	1.113E-11	4.764E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.149E-03	2.811E-03	1.850E-03	1.010E-04
SSE	157.5	2.679E-08	4.875E-09	1.438E-09	5.492E-10	3.113E-10	2.079E-10	1.060E-10	4.482E-11	2.302E-11	9.875E-12
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	1.812E-03	0.000E+00	2.564E-03	1.356E-03	4.645E-03	2.495E-03	5.032E-04
S	180.0	4.045E-08	7.688E-09	2.325E-09	9.037E-10	5.158E-10	3.458E-10	1.770E-10	7.509E-11	3.856E-11	1.651E-11
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.238E-03	1.676E-02	5.869E-03	6.807E-03	1.366E-03
SSW	202.5	4.759E-08	9.097E-09	2.767E-09	1.081E-09	6.192E-10	4.161E-10	2.138E-10	9.105E-11	4.684E-11	2.010E-11

		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.083E-03	9.487E-03	5.129E-02	1.971E-02	5.834E-03	1.401E-03
SW	225.0	4.184E-08	8.235E-09	2.548E-09	1.006E-09	5.799E-10	3.914E-10	2.021E-10	8.671E-11	4.481E-11	1.930E-11
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	3.028E-03	0.000E+00	0.000E+00	2.200E-03	3.198E-02	1.745E-02	2.086E-02	9.492E-03
WSW	247.5	3.106E-08	5.102E-09	1.413E-09	5.180E-10	2.892E-10	1.918E-10	9.713E-11	4.077E-11	2.087E-11	8.916E-12
		0	0	0	0	1008	5794	25835	25625	642	26351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.341E-03	8.922E-03	2.015E-02	8.389E-03	1.076E-04	1.887E-03
W	270.0	3.760E-08	7.270E-09	2.229E-09	8.755E-10	5.030E-10	3.388E-10	1.743E-10	7.433E-11	3.822E-11	1.631E-11
		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.349E-03	4.227E-02	8.238E-03	4.450E-04	9.117E-04
WNW	292.5	4.776E-08	8.853E-09	2.646E-09	1.023E-09	5.824E-10	3.899E-10	1.991E-10	8.400E-11	4.288E-11	1.817E-11
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	5.568E-03	0.000E+00	0.000E+00	0.000E+00	6.648E-03	1.263E-03	3.403E-03	1.125E-03
NW	315.0	5.051E-08	1.001E-08	3.104E-09	1.228E-09	7.047E-10	4.736E-10	2.427E-10	1.027E-10	5.236E-11	2.212E-11
		0	0	0	0	0	0	1168	769	7919	19737
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.276E-03	6.339E-04	3.329E-03	3.505E-03
NNW	337.5	4.006E-08	7.072E-09	2.051E-09	7.773E-10	4.370E-10	2.899E-10	1.463E-10	6.065E-11	3.058E-11	1.275E-11
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.519E-03	9.094E-04	6.327E-04	1.115E-03	1.003E-02

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap0 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
5.051E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	1660	0.09	2.181E-02	3.44
1.000E-10	163497	9.15	3.040E-01	47.97
1.000E-11	1714394	95.93	6.295E-01	99.33
4.224E-12	1787083	100.00	6.337E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; TACOMA SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap6
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :	0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR MID-ANGLE										
N 0.0	1.370E-08	2.450E-09	7.155E-10	2.727E-10	1.534E-10	1.017E-10	5.125E-11	2.117E-11	1.064E-11	4.413E-12
	0	0	0	1915	0	4330	765	0	22057	417243
	0.000E+00	0.000E+00	0.000E+00	4.193E-03	0.000E+00	3.537E-03	3.148E-04	0.000E+00	1.885E-03	1.479E-02

NNE	22.5	1.599E-08	3.080E-09	9.357E-10	3.651E-10	2.067E-10	1.374E-10	6.930E-11	2.857E-11	1.431E-11	5.895E-12
		0	0	0	0	553	4974	14804	12041	58778	287872
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.180E-04	5.490E-03	8.238E-03	2.763E-03	6.752E-03	1.363E-02
NE	45.0	1.407E-08	2.624E-09	7.832E-10	3.021E-10	1.703E-10	1.129E-10	5.679E-11	2.338E-11	1.172E-11	4.841E-12
		0	0	0	0	0	2135	13657	14840	45395	68241
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.936E-03	6.228E-03	2.786E-03	4.270E-03	2.652E-03
ENE	67.5	9.121E-09	1.625E-09	4.705E-10	1.773E-10	9.897E-11	6.522E-11	3.261E-11	1.337E-11	6.704E-12	2.787E-12
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	4.723E-03	0.000E+00	0.000E+00	0.000E+00	1.086E-03	1.993E-03	1.298E-03	3.385E-04
E	90.0	5.760E-09	9.539E-10	3.632E-10	9.586E-11	5.285E-11	3.463E-11	1.724E-11	7.075E-12	3.575E-12	1.510E-12
		0	0	0	0	663	456	2911	12676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.814E-04	1.268E-04	4.029E-04	7.201E-04	3.064E-04	9.392E-05
ESE	112.5	5.247E-09	9.595E-10	2.797E-10	1.051E-10	5.865E-11	3.865E-11	1.936E-11	8.017E-12	4.076E-12	1.740E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.651E-04	0.000E+00	1.510E-03	3.827E-04	2.185E-04	2.023E-04
SE	135.0	6.003E-09	1.006E-09	2.798E-10	1.024E-10	5.678E-11	3.740E-11	1.876E-11	7.798E-12	3.978E-12	1.703E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.107E-04	1.005E-03	6.610E-04	3.611E-05
SSE	157.5	9.572E-09	1.742E-09	5.138E-10	1.962E-10	1.113E-10	7.429E-11	3.789E-11	1.602E-11	8.225E-12	3.529E-12
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	6.477E-04	0.000E+00	9.163E-04	4.846E-04	1.660E-03	8.917E-04	1.798E-04
S	180.0	1.446E-08	2.747E-09	8.310E-10	3.229E-10	1.843E-10	1.236E-10	6.327E-11	2.683E-11	1.378E-11	5.899E-12
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.157E-03	5.989E-03	2.097E-03	2.432E-03	4.882E-04
SSW	202.5	1.701E-08	3.251E-09	9.888E-10	3.863E-10	2.213E-10	1.487E-10	7.641E-11	3.254E-11	1.674E-11	7.183E-12
		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.445E-04	3.390E-03	1.833E-02	7.043E-03	2.085E-03	5.007E-04
SW	225.0	1.495E-08	2.943E-09	9.106E-10	3.596E-10	2.072E-10	1.399E-10	7.224E-11	3.099E-11	1.601E-11	6.897E-12
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	1.082E-03	0.000E+00	0.000E+00	7.862E-04	1.143E-02	6.236E-03	7.453E-03	3.392E-03
WSW	247.5	1.110E-08	1.823E-09	5.050E-10	1.851E-10	1.034E-10	6.853E-11	3.471E-11	1.457E-11	7.457E-12	3.186E-12
		0	0	0	0	1008	5794	25835	35625	642	36351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.366E-04	3.188E-03	7.201E-03	2.998E-03	3.844E-05	6.742E-04
W	270.0	1.344E-08	2.598E-09	7.967E-10	3.129E-10	1.798E-10	1.211E-10	6.230E-11	2.656E-11	1.366E-11	5.829E-12
		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.197E-03	1.510E-02	2.944E-03	1.590E-04	3.258E-04
WNW	292.5	1.707E-08	3.164E-09	9.457E-10	3.656E-10	2.081E-10	1.393E-10	7.116E-11	3.002E-11	1.532E-11	6.492E-12
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	1.990E-03	0.000E+00	0.000E+00	0.000E+00	2.376E-03	4.512E-04	1.216E-03	4.019E-04
NW	315.0	1.805E-08	3.577E-09	1.109E-09	4.388E-10	2.518E-10	1.692E-10	8.673E-11	3.668E-11	1.871E-11	7.903E-12
		0	0	0	0	0	0	1168	769	7919	19737
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.135E-04	2.265E-04	1.190E-03	1.253E-03
NNW	337.5	1.432E-08	2.527E-09	7.328E-10	2.778E-10	1.562E-10	1.036E-10	5.229E-11	2.167E-11	1.093E-11	4.555E-12
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.002E-04	3.250E-04	2.261E-04	3.986E-04	3.583E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap6 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
1.805E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	0	0.00	0.000E+00	0.00
1.000E-10	24423	1.37	3.353E-02	14.80
1.000E-11	617465	34.55	1.784E-01	78.78
1.510E-12	1787083	100.00	2.265E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; TACOMA SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap12
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(22.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) :		0.0- 0.5	0.5- 1.0	1.0- 2.0	2.0- 3.0	3.0- 4.0	4.0- 5.0	5.0-10.0	10.0-15.0	15.0-25.0	25.0-50.0
SECTOR	MID-ANGLE										
N	0.0	1.307E-08	2.336E-09	6.824E-10	2.601E-10	1.463E-10	9.702E-11	4.888E-11	2.019E-11	1.015E-11	4.209E-12
		0	0	0	1915	0	4330	765	0	22057	417243
		0.000E+00	0.000E+00	0.000E+00	3.999E-03	0.000E+00	3.373E-03	3.003E-04	0.000E+00	1.798E-03	1.410E-02
NNE	22.5	1.526E-08	2.937E-09	8.924E-10	3.482E-10	1.972E-10	1.311E-10	6.610E-11	2.725E-11	1.364E-11	5.623E-12
		0	0	0	0	553	4974	14804	12041	58778	287872
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.756E-04	5.236E-03	7.857E-03	2.635E-03	6.440E-03	1.300E-02
NE	45.0	1.342E-08	2.503E-09	7.470E-10	2.882E-10	1.624E-10	1.077E-10	5.417E-11	2.230E-11	1.117E-11	4.617E-12
		0	0	0	0	0	2135	13657	14840	45395	68241
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.847E-03	5.940E-03	2.657E-03	4.073E-03	2.530E-03
ENE	67.5	8.700E-09	1.550E-09	4.488E-10	1.691E-10	9.439E-11	6.220E-11	3.110E-11	1.275E-11	6.394E-12	2.659E-12
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	4.504E-03	0.000E+00	0.000E+00	0.000E+00	1.036E-03	1.901E-03	1.238E-03	3.229E-04
E	90.0	5.493E-09	9.098E-10	2.510E-10	9.143E-11	5.041E-11	3.303E-11	1.644E-11	6.748E-12	3.410E-12	1.440E-12
		0	0	0	0	663	456	2911	12676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.684E-04	1.209E-04	3.843E-04	6.868E-04	2.923E-04	8.958E-05
ESE	112.5	5.005E-09	9.152E-10	2.668E-10	1.002E-10	5.593E-11	3.686E-11	1.847E-11	7.647E-12	3.888E-12	1.659E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.251E-04	0.000E+00	1.440E-03	3.650E-04	2.084E-04	1.929E-04
SE	135.0	5.725E-09	9.592E-10	2.668E-10	9.765E-11	5.416E-11	3.567E-11	1.790E-11	7.438E-12	3.794E-12	1.624E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.918E-04	9.582E-04	6.304E-04	3.444E-05
SSE	157.5	9.130E-09	1.661E-09	4.901E-10	1.872E-10	1.061E-10	7.085E-11	3.613E-11	1.528E-11	7.845E-12	3.366E-12
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	6.177E-04	0.000E+00	8.739E-04	4.622E-04	1.583E-03	8.505E-04	1.715E-04

S	180.0	1.379E-08	2.620E-09	7.926E-10	3.080E-10	1.758E-10	1.179E-10	6.034E-11	2.559E-11	1.314E-11	5.626E-12
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.103E-03	5.712E-03	2.000E-03	2.320E-03	4.656E-04
SSW	202.5	1.622E-08	3.100E-09	9.431E-10	3.685E-10	2.110E-10	1.418E-10	7.288E-11	3.103E-11	1.597E-11	6.851E-12
		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.101E-04	3.233E-03	1.748E-02	6.718E-03	1.988E-03	4.775E-04
SW	225.0	1.426E-08	2.807E-09	8.685E-10	3.430E-10	1.976E-10	1.334E-10	6.890E-11	2.955E-11	1.527E-11	6.578E-12
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	1.032E-03	0.000E+00	0.000E+00	7.499E-04	1.090E-02	5.948E-03	7.108E-03	3.235E-03
WSW	247.5	1.059E-08	1.739E-09	4.817E-10	1.766E-10	9.858E-11	6.536E-11	3.311E-11	1.390E-11	7.113E-12	3.039E-12
		0	0	0	0	1008	5794	25835	25625	642	26351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.979E-04	3.041E-03	6.868E-03	2.859E-03	3.667E-05	6.431E-04
W	270.0	1.282E-08	2.478E-09	7.599E-10	2.984E-10	1.715E-10	1.155E-10	5.942E-11	2.533E-11	1.303E-11	5.560E-12
		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.141E-03	1.441E-02	2.808E-03	1.517E-04	3.108E-04
WNW	292.5	1.628E-08	3.017E-09	9.020E-10	3.487E-10	1.985E-10	1.329E-10	6.788E-11	2.863E-11	1.462E-11	6.192E-12
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	1.898E-03	0.000E+00	0.000E+00	0.000E+00	2.266E-03	4.304E-04	1.160E-03	3.833E-04
NW	315.0	1.722E-08	3.412E-09	1.058E-09	4.185E-10	2.402E-10	1.614E-10	8.272E-11	3.499E-11	1.785E-11	7.538E-12
		0	0	0	0	0	0	1168	769	7919	19737
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.759E-04	2.161E-04	1.135E-03	1.195E-03
NNW	337.5	1.366E-08	2.410E-09	6.989E-10	2.649E-10	1.489E-10	9.882E-11	4.987E-11	2.067E-11	1.042E-11	4.344E-12
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.586E-04	3.100E-04	2.156E-04	3.802E-04	3.418E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap12 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
1.722E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	0	0.00	0.000E+00	0.00
1.000E-10	18003	1.01	2.695E-02	12.48
1.000E-11	617465	34.55	1.702E-01	78.78
1.440E-12	1787083	100.00	2.160E-01	100.00

A CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.

POLLUTANT ; hcb
SITE ; TACOMA SOURCE CATEGORY ; halfacre EMISSION TYPE ; cap24
REPORTED TABULAR VALUES WITHIN INDIVIDUAL SECTOR SEGMENTS : ISC ESTIMATED ANNUAL AVERAGE CONCENTRATION (UG/M3)
POPULATION (PERSONS)
POPULATION EXPOSURE (UG/YR)
POPULATION EXPOSURE = ANNUAL AVERAGE CONCENTRATION X POPULATION X ANNUAL BREATHING RATE(23.0M3/DAY X 365. DAYS/YR)

DISTANCES (KM) : 0.0- 0.5 0.5- 1.0 1.0- 2.0 2.0- 3.0 3.0- 4.0 4.0- 5.0 5.0-10.0 10.0-15.0 15.0-25.0 25.0-50.0

SECTOR	MID-ANGLE										
N	0.0	1.192E-08	2.130E-09	6.223E-10	2.372E-10	1.334E-10	8.847E-11	4.457E-11	1.841E-11	9.256E-12	3.838E-12
		0	0	0	1915	0	4330	765	0	22057	417243
		0.000E+00	0.000E+00	0.000E+00	3.647E-03	0.000E+00	3.076E-03	2.738E-04	0.000E+00	1.639E-03	1.286E-02
NNE	22.5	1.391E-08	2.679E-09	8.138E-10	3.175E-10	1.798E-10	1.195E-10	6.027E-11	2.485E-11	1.244E-11	5.127E-12
		0	0	0	0	553	4974	14804	12041	58778	287872
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.984E-04	4.775E-03	7.165E-03	2.403E-03	5.873E-03	1.185E-02
NE	45.0	1.223E-08	2.282E-09	6.812E-10	2.628E-10	1.481E-10	9.822E-11	4.940E-11	2.033E-11	1.019E-11	4.210E-12
		0	0	0	0	0	2135	13657	14840	45395	68241
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.684E-03	5.417E-03	2.423E-03	3.714E-03	2.807E-03
ENE	67.5	7.933E-09	1.414E-09	4.092E-10	1.542E-10	8.608E-11	5.672E-11	2.836E-11	1.163E-11	5.831E-12	2.424E-12
		0	0	1250	0	0	0	4149	18566	24114	15125
		0.000E+00	0.000E+00	4.108E-03	0.000E+00	0.000E+00	0.000E+00	9.449E-04	1.733E-03	1.129E-03	2.945E-04
E	90.0	5.009E-09	8.296E-10	2.289E-10	8.338E-11	4.597E-11	3.012E-11	1.499E-11	6.153E-12	3.109E-12	1.313E-12
		0	0	0	0	663	456	2911	12676	10674	7748
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.447E-04	1.103E-04	3.505E-04	6.263E-04	2.665E-04	8.168E-05
ESE	112.5	4.564E-09	8.345E-10	2.433E-10	9.140E-11	5.101E-11	3.361E-11	1.684E-11	6.973E-12	3.545E-12	1.513E-12
		0	0	0	0	1837	0	9713	5945	6674	14478
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.524E-04	0.000E+00	1.313E-03	3.329E-04	1.900E-04	1.759E-04
SE	135.0	5.221E-09	8.747E-10	2.433E-10	8.905E-11	4.938E-11	3.253E-11	1.632E-11	6.782E-12	3.460E-12	1.481E-12
		0	0	0	0	0	0	2726	16043	20693	2641
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.572E-04	8.738E-04	5.749E-04	3.140E-05
SSE	157.5	8.325E-09	1.515E-09	4.469E-10	1.707E-10	9.675E-11	6.461E-11	3.295E-11	1.393E-11	7.154E-12	3.069E-12
		0	0	0	411	0	1536	1593	12904	13501	6346
		0.000E+00	0.000E+00	0.000E+00	5.633E-04	0.000E+00	7.969E-04	4.215E-04	1.444E-03	7.755E-04	1.564E-04
S	180.0	1.257E-08	2.390E-09	7.228E-10	2.809E-10	1.603E-10	1.075E-10	5.503E-11	2.334E-11	1.198E-11	5.131E-12
		0	0	0	0	0	1166	11789	9733	21985	10306
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.006E-03	5.209E-03	1.824E-03	2.116E-03	4.246E-04
SSW	202.5	1.479E-08	2.827E-09	8.600E-10	3.360E-10	1.925E-10	1.293E-10	6.646E-11	2.830E-11	1.456E-11	6.247E-12
		0	0	0	0	419	2839	29876	26958	15509	8680
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.475E-04	2.949E-03	1.594E-02	6.126E-03	1.813E-03	4.354E-04
SW	225.0	1.300E-08	2.559E-09	7.920E-10	3.128E-10	1.802E-10	1.217E-10	6.283E-11	2.695E-11	1.393E-11	5.998E-12
		0	0	148	0	0	700	19699	25062	57958	61247
		0.000E+00	0.000E+00	9.413E-04	0.000E+00	0.000E+00	6.838E-04	9.938E-03	5.424E-03	6.482E-03	2.950E-03
WSW	247.5	9.654E-09	1.586E-09	4.392E-10	1.610E-10	8.989E-11	5.960E-11	3.019E-11	1.267E-11	6.486E-12	2.771E-12
		0	0	0	0	1008	5794	25835	25625	642	26351
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.276E-04	2.773E-03	6.263E-03	2.607E-03	3.344E-05	5.864E-04
W	270.0	1.169E-08	2.260E-09	6.929E-10	2.721E-10	1.563E-10	1.053E-10	5.418E-11	2.310E-11	1.188E-11	5.070E-12
		0	0	0	0	0	1231	30193	13802	1450	6961
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.041E-03	1.314E-02	2.560E-03	1.383E-04	2.834E-04
WNW	292.5	1.485E-08	2.752E-09	8.325E-10	3.179E-10	1.810E-10	1.212E-10	6.190E-11	2.611E-11	1.333E-11	5.646E-12
		0	0	262	0	0	0	4157	1872	9883	7710
		0.000E+00	0.000E+00	1.730E-03	0.000E+00	0.000E+00	0.000E+00	2.066E-03	3.925E-04	1.059E-03	3.496E-04
NW	315.0	1.570E-08	3.111E-09	9.648E-10	3.817E-10	2.190E-10	1.472E-10	7.543E-11	3.191E-11	1.627E-11	6.874E-12
		0	0	0	0	0	0	1168	769	7919	19737

		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.075E-04	1.970E-04	1.035E-03	1.089E-03
NNW	337.5	1.245E-08	2.198E-09	6.374E-10	2.416E-10	1.358E-10	9.012E-11	4.548E-11	1.885E-11	9.506E-12	3.961E-12
		0	0	0	0	0	1082	774	1299	4542	97970
		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.830E-04	2.927E-04	1.966E-04	3.467E-04	3.116E-03

50.0 KM RADIUS POPULATION EXPOSED AND EXPOSURE TO hcb
RESULTING FROM cap24 EMISSIONS UNDER ISC SOURCE CATEGORY halfacre
AROUND TACOMA

CONCENTRATION LEVEL (UG/M3)	CUMULATIVE POPULATION EXPOSED (PERSONS)	(%)	CUMULATIVE POPULATION EXPOSURE (UG/YR)	(%)
1.570E-08	0	0.00	0.000E+00	0.00
1.000E-08	0	0.00	0.000E+00	0.00
1.000E-09	0	0.00	0.000E+00	0.00
1.000E-10	15868	0.89	2.289E-02	11.62
1.000E-11	590866	33.06	1.532E-01	77.77
1.313E-12	1787083	100.00	1.970E-01	100.00

CUMULATIVE POPULATION EXPOSURE WAS ARRIVED AT BY ACCUMULATING
POPULATION EXPOSURES ASSOCIATED WITH INDIVIDUAL SECTOR SEGMENTS.